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The WELDING Journal

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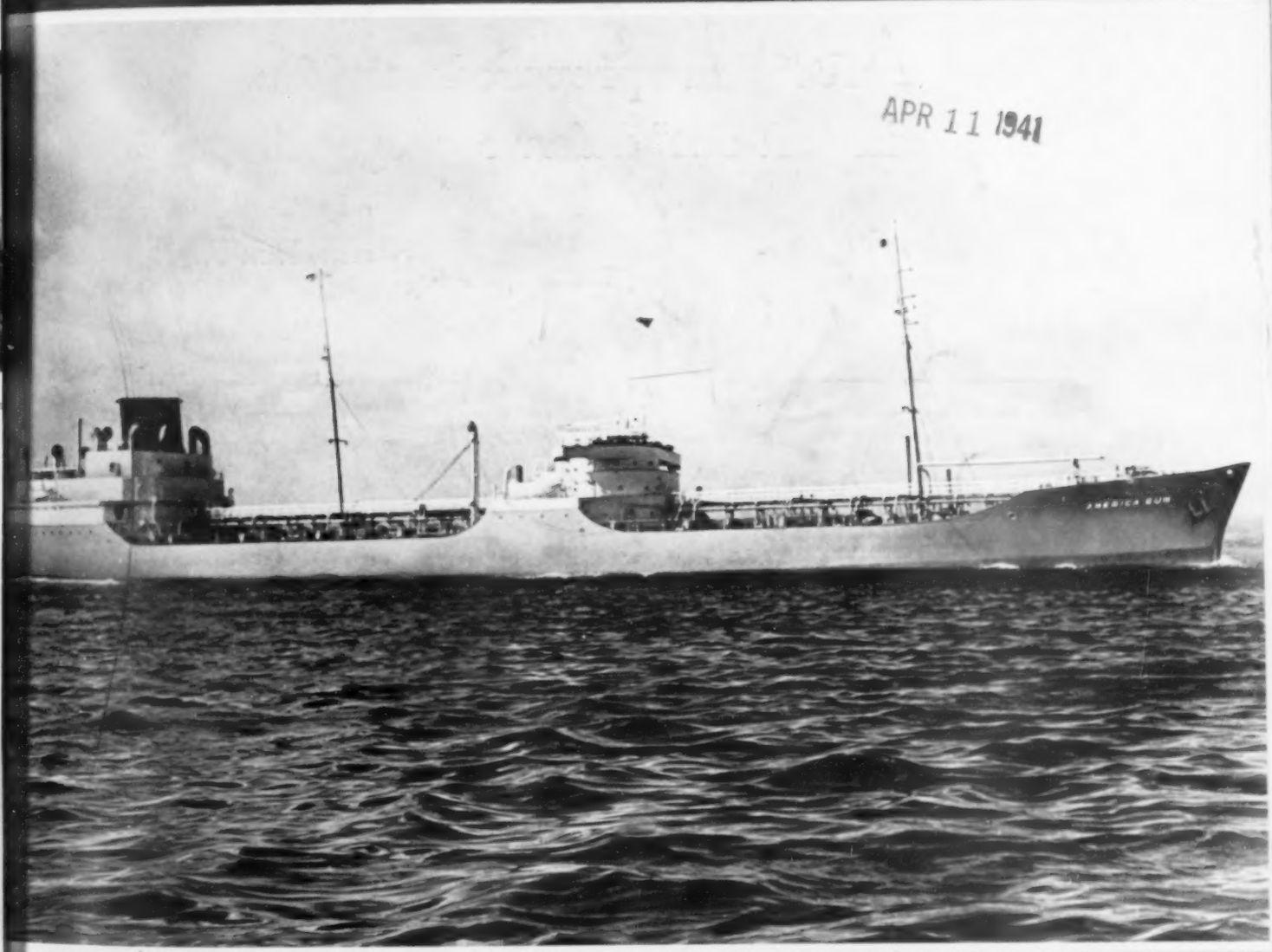

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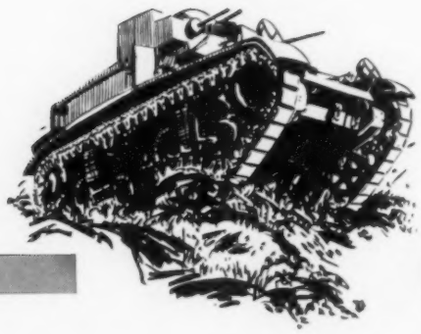

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Arc Welding Without Residual Shrinkage Stresses

By Ralph E. Spaulding*

IT IS well known that in the ordinary process of arc welding certain shrinkage stresses are set up (sometimes referred to as locked-in stresses) which cause shrinkage along the weld with consequent bending or warpage of the welded assembly. The difficulties encountered because of this are well known. A good illustration of such shrinkage and warpage is given by Mr. Samuel T. Smetters in the October 1939 issue of THE WELDING JOURNAL. In the September 1940 issue of THE WELDING JOURNAL an article by D. Rosenthal and J. Zábrs illustrates the relative magnitude of this shrinkage.

Before we can take steps to prevent the occurrence of shrinkage stresses due to welding it is necessary to know exactly what physical process causes the shrinkage.

In the welding process the application of intense heat to a localized area causes that highly heated area to expand. This localized area cannot expand in a normal manner, that is, in all directions in accordance with the temperature change times its coefficient of thermal expansion, being restrained by the larger areas of relatively colder metal surrounding the smaller area of hot metal (usually on all sides except the top), and therefore elastic deformation, or plastic deformation, takes place in the highly heated area along the line of least resistance. The fact that the modulus of elasticity as well as the yield strength of highly heated metal is relatively low makes this deformation comparatively easy.

To illustrate this assume a bar, as in Fig. 1, and lay a welding bead throughout its length along its center line, *y-y*.

At any cross section of the bar at the moment the weld bead has just been laid we have the condition described above, that is, an elongated spot of highly heated metal which has undergone plastic deformation, its high relative temperature having caused it to expand. Because of the vastly greater strength of the whole bar at normal temperature as against the relative softness and weakness of the hot spot, this highly heated spot

* The Aetna Steel Construction Co., Jacksonville, Fla.

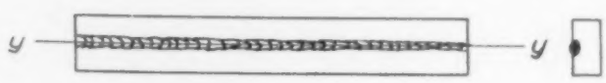


Fig. 1

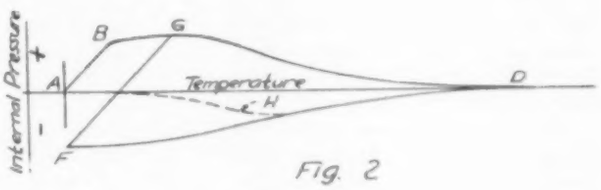


Fig. 2

cannot expand along the axis of the bar *y-y* but can, and does, expand and plastically deform outwardly and away from the mass of the bar. Therefore, taking the entire bead along the axis *y-y* into consideration it is evident that the bead, together with the adjacent metal which has been highly heated, has an absolute axial length along the axis *y-y*, *in its highly heated state*, which is the same as the axial length of the bar itself *at its relatively colder temperature before welding*.

As the entire bar plus its deposited weld bead again becomes of one uniform temperature this formerly highly heated area obviously undertakes to contract in all directions, including along the axis *y-y*, in accordance with its coefficient of thermal contraction. While relatively free to contract inwardly, that is, from the face toward the root of the weld, it is restrained from contracting in *all* directions, particularly along the axis *y-y*, by the superior bulk of the surrounding cooler metal so that the weld area (comprising the weld bead plus the highly heated parent metal) is subjected to tension along the axis *y-y*.

To more fully describe this physical process we refer to Fig. 2, which is a graph of temperature change and internal pressure of the spot undergoing heating and subsequent cooling as outlined above.

Referring to Fig. 2, the horizontal line running through *A-D* represents the measure of change in temperature, and the point *D* on this line the highest temperature to which the spot is subjected. Vertical distances above the horizontal temperature line represent the measure of internal pressure produced by the change in temperature, and distances below the horizontal line represent the measure of internal negative pressure—or tension—in the spot undergoing temperature change.

For corresponding unit areas let *t* denote change in temperature; *d*, deformation; *E*, modulus of elasticity; *Y*, elastic limit, or yield strength; *K*, coefficient of thermal expansion; *f*, unit fiber stress (or pressure).

Then, starting at room temperature A, as heat is applied to the spot the metal expands in all directions where free to do so in accordance with the well-known formula

$$d = tK$$

As previously stated it is not free to expand in all directions, particularly not along the axis y-y. In the direction in which expansion is restrained an internal pressure is built up in accordance with the formula

$$f = dE = tKE$$

Plastic deformation cannot take place until the internal stress has become as great as the yield strength of the metal, or until

$$f = Y$$

This point is denoted by B in the diagram (Fig. 2). At the point B no plastic deformation has as yet taken place but the internal stress is just equal to the yield strength. If, then, the spot be allowed to cool again to room temperature, without further heating, the internal pressure would decrease back down to zero at A, and there would remain no locked-in stress. If, however, heat continues to be added beyond point B, plastic deformation will take place and continue so long as heat is added, the internal stress always being equal to the yield strength, increasing as yield strength increases and decreasing to zero as the metal reaches the melting point, at D.

As the temperature starts (from D) reducing back to normal a condition the reverse of the above takes place, the metal becomes subjected to negative pressure, or tension, in accordance with the same law of $f = tKE$ as above. This tension increases until it equals the yield strength of the metal (at the then instant temperature) whereupon plastic deformation again begins to take place, and plastic deformation continues so long as the temperature continues to drop, the internal tension always being equal to the then instant yield strength, until, when the metal has cooled back to its original starting temperature, F, the internal tension, particularly along axis y-y, is equal to the full yield strength of the metal.

The temperature change necessary, in most structural steels, to produce an internal pressure equal to the yield strength, or $t = Y/KE$, is approximately 200° F.

All metal which is adjacent to the weld but not subjected to an increased temperature of more than approx. 200° F. returns to its normal state upon cooling without locked-in stresses, its temperature-pressure curve being A to B and B back to A.

But if a spot be heated to a maximum of twice 200, or approx. 400° F. (represented by point G on the curve), its temperature-pressure curve during the complete cycle of heating and cooling is: A to B at which point plastic deformation starts, B to G during which period plastic deformation is taking place, and the cooling period of G to F during which no plastic deformation takes place but the internal stress changes from full yield strength in compression at G to full yield strength in tension at F, where the temperature is again normal.

Therefore all metal of the weld area in which the change in temperature has not exceeded approx. 200° F. has no locked-in stresses.

Metal in which the temperature rise has ranged from approx. 200° F. to approx. 400° F. contains locked-in stresses varying from zero to full yield strength.

All metal in which the temperature rise has exceeded approx. 400° F. contains, after the weld has cooled, locked-in stresses equal to the full yield strength of the metal.

This tension is balanced by compression in the remainder of the metal with resultant shrinkage and warpage.

All welding shops are familiar with this shrinkage and have their own methods of counteracting the warpage, usually by producing, by applied heat, another zone of shrinkage on the opposite side of the center of gravity of the piece (heat balancing) leaving the welded assembly slightly shorter than the original length, and leaving in the assembly two sets of locked-in stresses instead of one.

The locked-in stresses can be relieved in an annealing oven, but it is expensive and usually does not restore the warped assembly to its original shape. Furthermore, in a great majority of cases it is practically impossible to apply this method.

It is, however, possible and comparatively easy and simple to prevent the initial development of this shrinkage stress in the weld area.

As has been above described, the weld area (consisting of deposited weld metal plus all of the adjacent original metal which has been heated to at least approx. 400° F. above its original temperature) is, while cooling, trying to adapt its normal axial length to that of the surrounding original metal but cannot do so by itself alone. If only a very little assistance is given during this period of cooling the axial length of the weld area can readily adapt itself to the normal axial length of the original metal. Obviously this assistance must take place during the initial cooling of the weld area.

It can be accomplished by pressing or light hammering of the weld area while it is cooling (vibratory pressure is best or pressure only if welding process is continuing). This added pressure, applied at right angles to the axis of the weld, can usually be best accomplished by the use of a light pneumatic or electric hammer having a tool face adapted to the desired size and contour of the weld. If applied at the right time, that is, while the yield strength of the hot weld is relatively low, only a small amount of effort is needed and all shrinkage tendency is found to have been eliminated. The temperature-pressure curve during this operation is illustrated by the dotted line H, Fig. 2.

Our shop has used this method† on certain welded assemblies for over a year with perfect results.

A test was made under the supervision of the Pittsburgh Testing Laboratories and their report shows:

(1) That the tendency to shrinkage is eliminated.
(2) That the weld when treated as described is stronger than an equivalent untreated weld.

This method must not be confused with so-called "peaning" or hammering of the weld area after it has cooled to such an extent that the elastic limit, or yield strength, of the area has again approximated that of the original metal. Nor should it be compared to reheating of the weld area, with or without treatment while heated, since no heat produced by a flame can even approximate the same relative heat penetration with corresponding surface intensity of that resulting from an electric arc. In both of these latter methods counterbalancing locked-in stresses may be introduced which will overcome warpage but the welded assembly is nevertheless still subjected to high internal stresses, and often the physical structure of the metal is disturbed and weakened.

† The Aetna Iron & Steel Co. has patents covering this above-described method.

Welding of Copper and Red Brass*

By J. J. Vreeland† and J. Babin†

INTRODUCTION

COPPER has long enjoyed a high place in industry because of its excellent corrosion resistance, but in the field of welding, competition has been keen since the introduction of alloys of higher strength and with ability to be fabricated by welding. This paper has been written to show that copper can be welded satisfactorily, with physical properties of the welded joint to meet code requirements.

Oxyacetylene welding of copper has been used for many years, and with it fairly satisfactory work has been done, using deoxidized copper and silver bearing welding rods. Considerable development work and wide application of copper welding have been done in the past three years, but the general results obtained have not been entirely satisfactory for economical commercial fabrication.

The most economical method of welding copper and its alloys has proved to be the carbon arc, but for satisfactory results the welding rod used cannot be pure copper. The use of a bronze rod will meet with objection from chemical industries because of the different corrosion resistance of the joint. It is the authors' suggestion that test welds, made with the bronze rod recommended, be subjected to the corrosive liquors in question before final judgment is passed. Carbon arc welding with the so-called "long arc" method and phosphor bronze welding rods has been successfully used, but the general results have been somewhat discouraging. The main objection to this type of rod, from a welding viewpoint, is the poor ductility of the joint and the presence of pin holes.

A point of great interest to the industry is that too much time has been spent in attempting to perfect the welding of electrolytic copper, when success could easily be obtained by using deoxidized copper. Most of the troubles encountered with copper welding has been due to the type of copper used.

FUSION WELDING

Electrolytic copper, containing a small percentage of oxygen in the form of copper-cuprous oxide eutectic, cannot be generally joined by any method of welding which involves a high percentage of reducing gases. At the elevated temperatures required for welding a tendency for reduction of the cuprous oxide is present, which results in a zone of embrittled metal adjacent to the weld. The slower the lineal speed of welding the wider this zone becomes and the poorer the results.

For this reason it is not advisable to gas weld electrolytic copper. Carbon arc welding produces excellent results, but because of the necessity of using a phosphor bronze type rod, the physical properties obtained in the weld metal are not suitable to withstand most service

* Presented at the Annual Meeting, A. W. S., Cleveland, Oct. 21 to 25, 1940.
† Welding Engineers, Chase Brass & Copper Co., Inc., Waterbury, Conn.

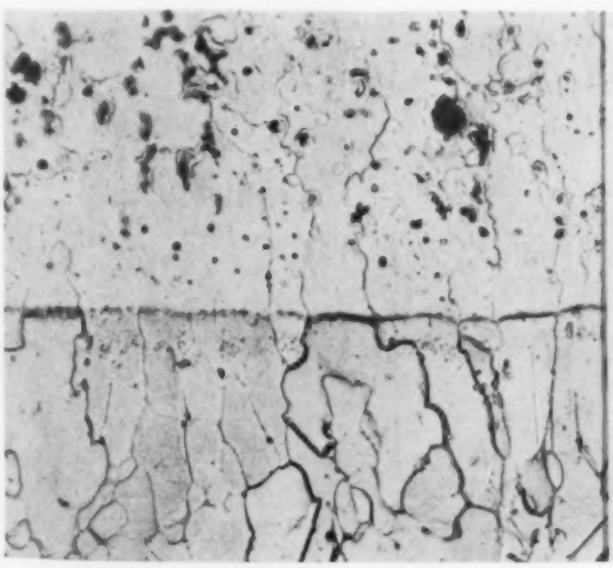


Fig. 1—Carbon Arc Weld of Electrolytic Copper Using High-Tin Phosphor Bronze Welding Rod. Note the Intergranular Bond and Porosity in Weld Metal. Strength of Joint 27,900 Psi
Mag. 75 X Etchant—H_2O_2 + NH_4OH

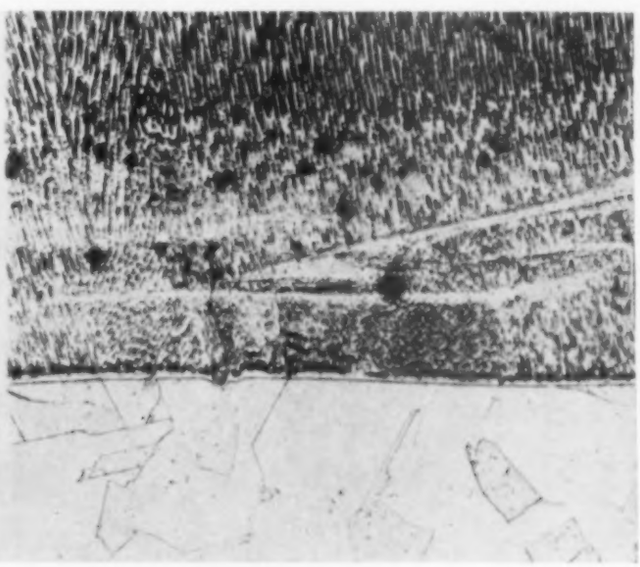


Fig. 2—Junction of Weld Metal and Base Metal of Weld in Fig. 3. Note Structure of Weld Metal and the Intergranular Bond at the Junction
Mag. 75 X Etchant—Chromic Acid

TABLE I

CARBON ARC WELDING ELECTROLYTIC COPPER

THICKNESS BASE METAL	MITRE	ROOT APER.	FILLER ROD TYPE	FILLER ROD SIZE	CARBON DIA.	CLOSED CIRCUIT AMPS.	CLOSED CIRCUIT VOLTS	TENSILE STRENGTH P.S.I.	FREE BEND %
1/16"	None	3/32"	Low Tin	1/8"	1/4"	140-150	30-35	29,800	- -
1/8"	None	3/32"	Low Tin	3/16"	5/16"	180-200	35-40	27,450	- -
3/16"	45°	1/16"	Low Tin	5/16"	3/8"	280-300	40-45	27,600	45
1/4"	45°	1/8"	Low Tin	3/8"	1/2"	540	55	26,100	32
1/4"	45°	1/8"	Low Tin	3/8"	1/2"	540	55	30,400	28 *
3/8"	45°	3/32"	Low Tin	1/2"	1/2"	No Results			
1/16"	None	3/32"	High Tin	1/8"	1/4"	160	35	27,500	- -
1/8"	None	3/32"	High Tin	3/16"	5/16"	220-240	35-40	28,400	- -
3/16"	45°	1/16"	High Tin	5/16"	3/8"	300-320	45-50	30,400	21.5
1/4"	45°	1/8"	High Tin	3/8"	1/2"	520	55	30,600	31
3/8"	45°	3/32"	High Tin	1/2"	1/2"	520-560	55	27,500	18
1/16"	-	3/32"	Silicon Bronze	1/8"	1/4"	130-140	25-30	12,250	- -
1/8"	-	3/32"	Silicon Bronze	3/16"	5/16"	210	35	17,100	- -
3/16"	45°	1/16"	Silicon Bronze	5/16"	3/8"	280-300	40-45	21,200	18
1/4"	45°	1/8"	Silicon Bronze	3/8"	1/2"	560	50	15,800	3.5
** 3/8"	45°	3/32"	Silicon Bronze	(1/4"	1/2"	400	35-40		
				(1/4"	1/2"	400	35-40	15,200	3.0
				(5/16"	1/2"	400	35-40		

* Weld peened and annealed.
** Multiple bead welding.

TABLE II

CARBON ARC WELDING DEOXIDIZED COPPER

THICKNESS BASE METAL	MITRE	ROOT APER.	FILLER ROD TYPE	FILLER ROD SIZE	CARBON DIA.	CLOSED CIRCUIT AMPS.	CLOSED CIRCUIT VOLTS	TENSILE STRENGTH P.S.I.	FREE BEND %
1/16"	None	3/32"	Silicon Bronze	1/8"	1/4"	120-140	20	32,700	-
1/8"	None	3/32"	Silicon Bronze	3/16"	5/16"	220-230	35	31,600	-
3/16"	45°	1/16"	Silicon Bronze	5/16"	3/8"	300	40	30,500	38.5
1/4"	45°	1/8"	Silicon Bronze	3/8"	1/2"	560	50	30,750	41
* 3/8"	45°	3/32"	Silicon Bronze	(1/4"	1/2"	400	35-40		
				(1/4"	1/2"	420	35-40	32,500	43
				(5/16"	1/2"	420-440	35-40		
* 1/2"	45°	3/32"	Silicon Bronze	(1/4"	3/8"	350	35		
			Silicon Bronze	(5/16"	1/2"	540	35	31,650	48
			Silicon Bronze	(3/8"	1/2"	540	40		
* 3/4"	37-1/2°	3/32"	Silicon Bronze	(5/32"	3/8"	340-360	33-35		
			Silicon Bronze	(1/4"	1/2"	400-440	35-40		
			Silicon Bronze	(5/16"	1/2"	460-480	35-40	30,450	37.6
			Silicon Bronze	‡ (3/8"	1/2"	440-480	35-40		
			Silicon Bronze	‡ (5/16"	1/2"	440-480	35-40		
5/16"	45°	1/16"	Low Tin	5/16"	3/8"	300	40	28,000	-
1/4"	45°	1/8"	Low Tin	3/8"	1/2"	520	55	29,800	-
** 1/4"	45°	1/8"	Low Tin	3/8"	1/2"	520	55	31,000	-

* Multiple bead welding. Plates preheated.
** Weld peened and annealed.
‡ Parallel beads used to minimize heat effect on base metal

TABLE III

OXYACETYLENE WELDING DEOXIDIZED COPPER

GAGE BASE METAL	MITRE	TORCH TIP	FILLER ROD TYPE	FILLER ROD SIZE	TENSILE STRENGTH P.S.I.	FREE BEND %
1/8"	-	#10	Silicon-Copper	1/8"	29,800	-
3/16"	45°	#12	Silicon-Copper	5/32"	26,800	50
1/4"	45°	(#12 Weld (#10 Aux.	Silicon-Copper	3/16"	28,100	46
3/8"	45°	(#14 Weld. (#12 Aux.	Silicon-Copper	1/4"	30,000	56
1/2"	45°	(#15 Weld (#12 Aux.	Silicon-Copper	1/4"	27,500	51

Note: #10 tip used on preheating torch for 1/8" and 3/16" copper.

TABLE IV

OXYACETYLENE WELDING COPPER TUBE AND PIPE

NOMINAL SIZE AND TYPE	MITRE	TORCH TIP	TYPE OF WELD	FILLER ROD TYPE	FILLER ROD SIZE	TENSILE STRENGTH P.S.I.
2" S.P.S. (.250 wall)	45°	#10	Rolling	Silicon-Copper	5/32"	28,500
6" Type L (.140 wall)	-	#10	Rolling	Silicon-Copper	5/32"	31,900
6" Type L	-	#10	Vertical-Horizontal	Silicon-Copper	5/32"	28,600
6" Type L	-	#10	Stationary	Silicon-Copper	5/32"	30,700

Note: #10 tip used on preheating torch for 6" Type L water tube.

TABLE V

OXYACETYLENE WELDING RED BRASS

FORM	THICKNESS	TYPE WELD	MITRE	TORCH TIP	FILLER ROD TYPE	FILLER ROD SIZE	TENSILE STRENGTH P.S.I.	FREE BEND %
2" S.P.S. Pipe	5/16"	Rolling	45°	#9	Low Sil. Brze.	5/32"	38,200 R	
6" S.P.S. Pipe	1/4"	Rolling	45°	#12	Low Sil. Brze.	3/16"	(37,700 R (35,300	
		Stationary	45°	#10	Low Sil. Brze.	3/16"	(37,300 R (35,500	
		Vertical-Horizontal	45°	#10	Low Sil. Brze.	3/16"	(37,200 R (35,200	
4" Ex. Hvy. Pipe	0.341"	Stationary	45°	#10 Weld. #10 Aux.	Low Sil. Brze.	3/16"	(36,900 R (36,000	
Plate	1/2"	Forehand	37-1/2°	#12 Weld #10 Aux.	Low Sil. Brze.	1/4"	(37,000 R (34,000	61

Note: #10 tip used on preheating torch for 6" S.P.S. pipe.

R - Indicates reinforced weld.

Tensile strength 1/2" Red Brass plate material, 44,000 p.s.i.

TABLE VI

CARBON ARC WELDING RED BRASS

THICKNESS BASE METAL	MITRE	ROOT APER.	FILLER ROD TYPE	FILLER ROD SIZE	CARBON DIA.	CLOSED CIRCUIT AMPS.	CLOSED CIRCUIT VOLTS	TENSILE STRENGTH P.S.I.	FREE BEND %
1/8"	-	3/32"	High Sil. Brze.	5/16"	5/16"	180-220	30-35		
3/16"	45°	1/16"	High Sil. Brze.	5/32"	1/4"	150-190	25-30		
				3/16"	5/16"	180-220	30-35		
1/4"	45°	1/16"	High Sil. Brze.	3/16"	5/16"	170-210	30-35		
				1/4"	3/8"	200-260	30-35		
3/8"	45°	3/32"	High Sil. Brze.	3/16"	3/8"	180-220	28-30		
				1/4"	3/8"	200-260	30-35		
				1/4"	1/2"	240-300	30-35		
1/2"	45°	3/32"	High Sil. Brze.	3/16"	3/8"	200-220	28-30		
				1/4"	3/8"	240-260	30-35	(41,700 R	65
				1/4"	1/2"	300-320	33-35	(37,650	
			*	(5/16"	1/2"	300-320	33-35		
				(1/4"	1/2"	320-340	33-35		

*Parallel beads used to minimize heat effect on base metal
Tensile strength of 1/2" red brass base metal, 44,000 p.s.i.
R- Indicates reinforced weld.

conditions. This is unfortunate, for otherwise the phosphor bronze type rod, which is the only suitable rod for this kind of welding, permits high lineal welding speeds, because of its excellent fluidity and ability to withstand the high heats required. Silicon bronze welding rods containing 3.0% silicon have the ability to withstand the high welding heats, but the lineal welding speeds must be reduced about 40% to permit the retention of dense weld metal. The physical properties of a joint made with silicon bronze on electrolytic copper are very poor because of the wider zone of reduction of the cuprous oxide particles.

Table 1 illustrates the expected results when electrolytic copper is welded by the carbon arc method using a low-tin phosphor bronze, a high-tin phosphor bronze, and silicon bronze welding rod. Because of the higher welding speeds satisfactory tensile properties are obtained using the phosphor bronze type rods. Ductility values, however, are erratic, and for this reason some trouble may be expected in service when welded units are subjected to pulsating pressures. It should be pointed

Fig. 3—Carbon Arc Weld of Deoxidized Copper Using Silicon Bronze Welding Rod. Strength of Joint 32,300 psi
Mag. 2 X Etchant—Chromic Acid

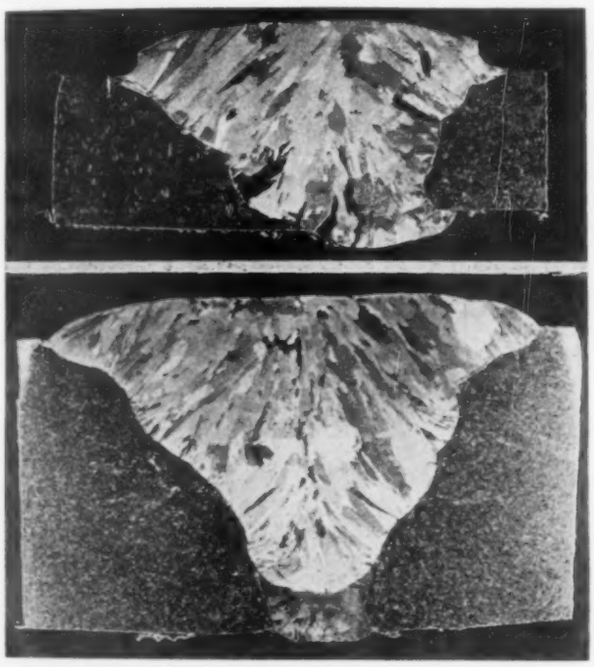


Fig. 4—Carbon Arc Weld on 3/4-Inch Deoxidized Copper Using Silicon Bronze Welding Rod. Strength of Joint 32,400 Psi
Mag. 2 X Etchant—Chromic Acid

out that copper heavier than 3/8-inch should not be carbon arc welded, since, using this type welding rod, multiple bead welding has not proved successful, due to hot-shortness of the deposited weld metal. The density of the weld metal is not satisfactory, because of the evolution of phosphorus, whose presence in the fabrication of pressure vessels gives considerable trouble, causing leaks.

Figure 1 shows the zone adjacent to weld metal in a joining of electrolytic copper by the carbon arc method using high-tin phosphor bronze as a welding rod.

The use of deoxidized copper, which contains no cuprous oxide, immediately eliminates speed of welding as a factor determining results obtained. Since silicon bronze deposits weld metal superior to phosphor bronzes, par-

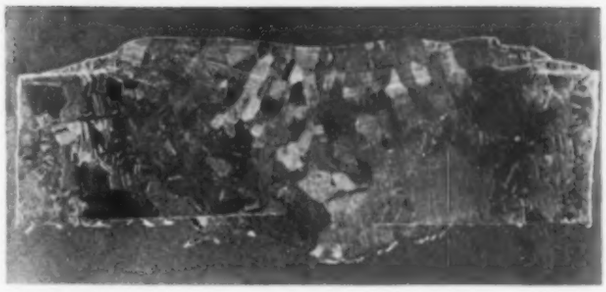


Fig. 5—Oxyacetylene Weld on 1/4-Inch Deoxidized Copper Using Silicon Copper Welding Rod. Strength of Joint 30,000 Psi
Mag. 2 X Etchant—Chromic Acid

ticularly as to density and ductility, it is expected that this material will receive consideration for copper welding to obtain excellent physical properties of the welded joint.

CARBON ARC WELDING DEOXIDIZED COPPER

The use of deoxidized copper for welding work eliminates faulty results attributable to the base metal in which there has been embrittling action due to cuprous oxide reduction. This is true only of oxyacetylene and carbon arc welding. The success of this type of welding depends upon the choice of welding rod and the capacity of heat available. It must be remembered that because of the high thermal conductivity of copper high amperages and voltages are required to compensate for the high rate of dissipation. For oxyacetylene welding, heat dissipation is a problem of approximately the same magnitude as in the welding of electrolytic copper.

In Table 2 are shown the approximate values of amperages and voltages. It is readily noted that for sufficient flexibility in range of thicknesses a 600-ampere machine should be used, capable of holding an arc drawing at least 50 volts while welding. It is acceptable practice on gages 1/4 inch and heavier to preheat the copper slightly to ensure more sound weld metal and to lower the starting heat requirements.

The choice of welding rod is now based on the ability to produce sound weld metal at the temperatures re-

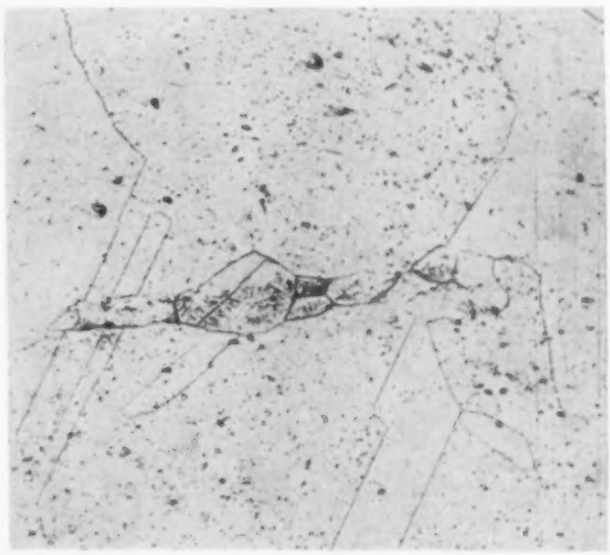


Fig. 6—Junction of Weld Metal and Base Metal in Weld Shown in Fig. 5. Note the Intergranular Bond and Equiaxed Structure of Weld Metal
Mag. 75 X Etchant—Chromic Acid

Fig. 7 (Left)—Right Angle Joint Made by Carbon Arc Welding on Square Copper Tubular Bus, Using Low-Tin Phosphor Bronze. Outside Corner of Weld Made by Oxyacetylene Method Using Silicon Copper Welding Rod

quired. The resulting ductility of the deposited weld metal is also of importance. Through extensive investigations it has been proved that the silicon bronze type rod containing approximately 3% silicon is a superior rod for the carbon arc welding method. The weld metal is not extremely fluid under the arc, as is the case with phosphor bronze rods. Welding speeds must then be much slower to insure satisfactory density of weld metal. To obtain maximum density of weld metal a flux designed to slag off silicon oxide must be used, in the same manner as recommended for silicon bronze welding by the carbon arc method.

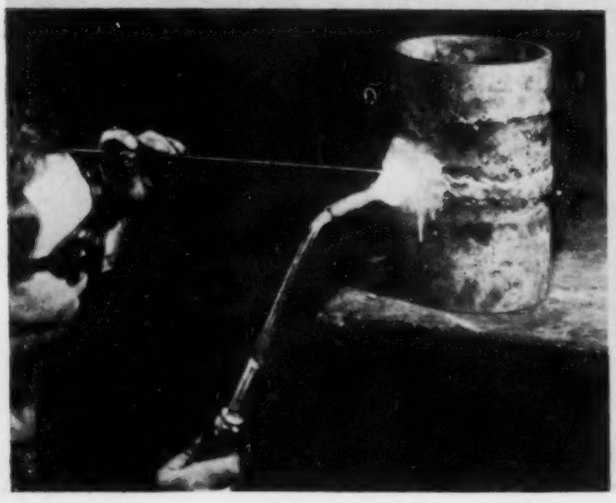
To insure ease of penetration gages of copper $^{3}/_{16}$ inch and heavier should be beveled at the edges that are to be joined. A root aperture, varying with the thickness,

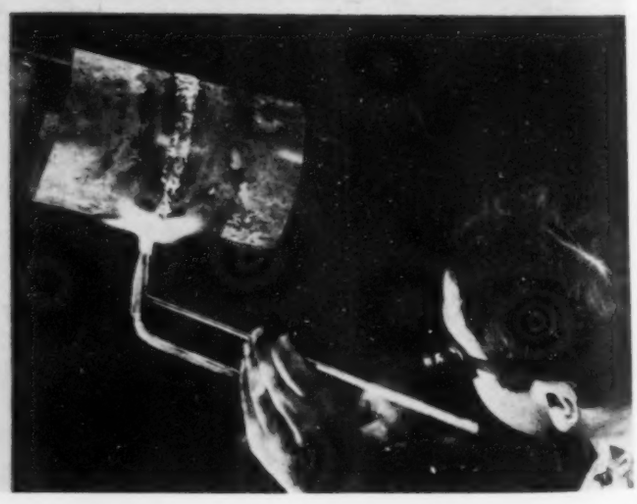
Fig. 8 (Upper Left)—Set-Up Showing Carbon Arc Method for Welding Right Angle Joints on Square Copper Tubular Bus. Low-Tin Phosphor Bronze Rod Used to Maintain Good Joint Conductivity

Fig. 9 (Upper Right)—Top Section of an All-Welded Copper Range Boiler, Welded with Carbon Arc Using Silicon Bronze Welding Rod. Note the Uniform Appearance of Weld Beads. Gage of Shell 0.042, Gage of Head 0.064 Inch. Test Pressure 200 Lb. Working Pressure 85 Lb. Pulsating Test 200,000 Cycles from 0 Lb. to 85 Lb.

Fig. 10 (Lower Left)—Oxyacetylene Welding of Sample 6 Inches S.P.S. Red Brass Pipe in a Vertical-Horizontal Position

Fig. 11 (Lower Left)—Oxyacetylene Welding Sample 6 Inches S.P.S. Red Brass Pipe in an Overhead Position (Stationary Weld)





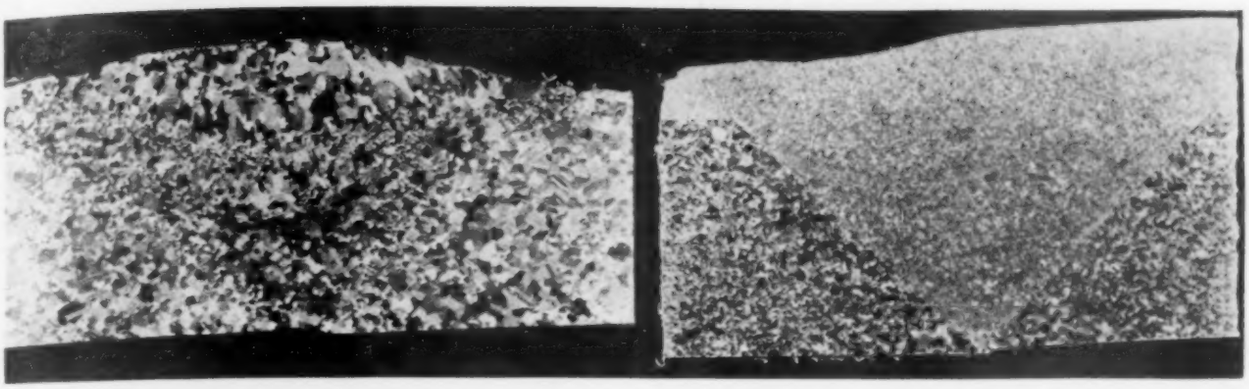


Fig. 12—Typical Oxyacetylene Weld on 1/2-Inch Red Brass Plate Using Low-Silicon Bronze Welding Rod. Strength of Joint 37,000 Psi. Note the Uniformity of Grain Structure and the Intergranular Bond Indicating Fusion of Weld Metal and Base Metal
Mag. 2 1/2 X Etchant—Chromic Acid

Fig. 14—A True Braze or "Bronze-Weld" on 1/2-Inch Red Brass Plate. Note the Sharp Line Between Braze and Base Metal. Strength of Joint Approximately 30,000 Psi
Mag. 3 X Etchant—H_2O_2 + NH_4OH

should also be used, as shown in Table 2. In the welding of thicknesses 3/8 inch and heavier it is suggested that multiple-bead welding be done. This insures excellent penetration and the ability to weld thicknesses up to 1 1/4 inch. The weld metal does not show any tendency to crack when using this multiple-bead method of welding.

All carbon arc welding of copper should be done in a downhand position, and the joint should be backed up with a copper chill bar or strip. If a bar is to be used and removed after welding, the thickness should not be less than 3/8 inch. It is recommended that a groove approximately 1/4 inch wide and 1/32 inch deep be machined in the bar to aid in obtaining proper penetration. Often a chill strip, approximately 1/8 inch thick, could be used and left as a reinforcement on the underside of the weld.

Figures 2, 3 and 4 are carbon arc welds of copper using the silicon bronze weld. It is not recommended that the carbon arc method be used for copper pipe welding unless a chill strip is used and that all welds are rolling welds. Due to the necessity of high heats, burning through would result if no chill strip were used. It is impossible to weld by this method in a vertical or overhead position.

OXYACETYLENE WELDING DEOXIDIZED COPPER

Oxyacetylene welding of copper has been for a number of years the only method capable of furnishing satisfactory results. A number of different welding rods such as phosphorus deoxidized copper, electrolytic copper, and silver bearing deoxidized copper containing approximately 1% silver have been used, with varying results. The use of electrolytic copper tends toward a highly porous weld, with tensile strengths (nonreinforced) running approximately 18,000 psi. The rod handles satisfactorily while using a flux designed for copper welding. The use of phosphorus deoxidized and the silver bearing deoxidized copper rods has improved the density of the deposited weld metal to such an extent that tensile values approximate 25,000 psi. The main objection to these rods was found in the poor handling, due to the high fluidity of the weld metal. For gages of copper under 5/16 inch being welded in the horizontal position, the results obtained are satisfactory. The high fluidity tends to permit faster lineal welding speed; and for gages 5/16 inch and heavier this high fluidity increases the likelihood of a brazed joint instead of a

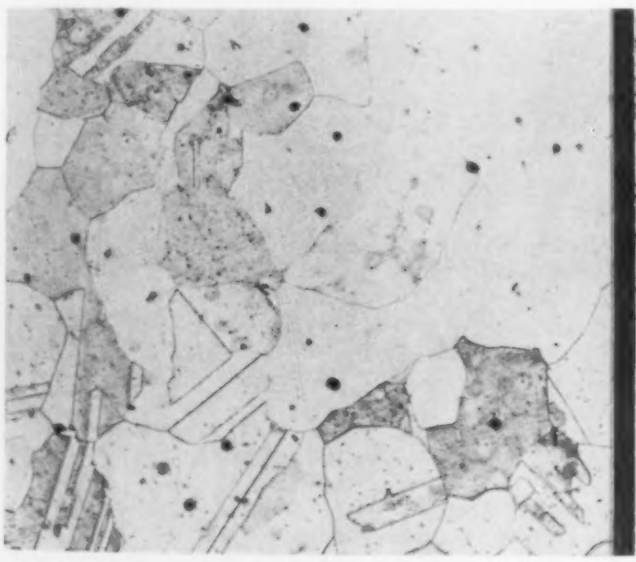


Fig. 13—Junction of Weld Metal and Base Metal Showing Perfect Intergranular Bond, as Shown in Fig. 12
Mag. 75 X Etchant—Chromic Acid

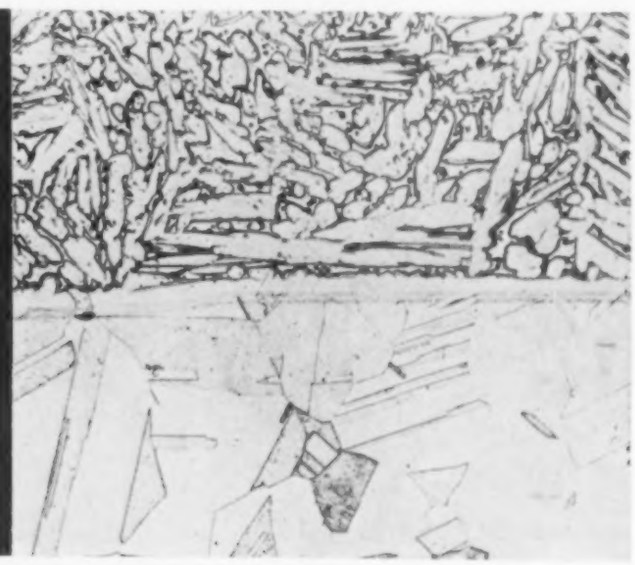


Fig. 15—Junction of "Bronze-Weld" Shown in Fig. 14
Mag. 75 X Etchant—H_2O_2 + NH_4OH

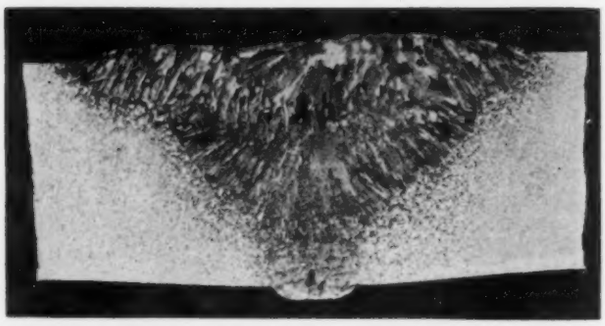


Fig. 16—1/2-Inch Red Brass Plate Carbon Arc Welded Using High Silicon Bronze Welding Rod. Note the Small Effect of the Welding on the Base Material. Strength of Weld 41,700 Psi
Mag. 2 X Etchant—Chromic Acid

weld. The resulting tensile strengths (nonreinforced) are much less than 25,000 psi. Because of this high fluidity extreme difficulty is encountered when attempting vertical-horizontal welds and overhead welds. When attempting this type of weld, there is a tendency for the highly fluid weld metal to run out of the joint.

The use of a silicon copper welding rod containing approximately 0.15% to 0.3% silicon produces exceptional results as to tensile strength and ease of welding in all positions. Using a deoxidized copper rod sound weld deposits are obtained. The presence of the small amount of silicon lowers the apparent fluidity so that a smaller pool of weld metal is obtained during the process of welding. Positive fusion is more certain because of the lesser tendency of the weld metal to run much ahead of the welding flame. The same sluggishness of weld metal makes vertical-horizontal and overhead welding easier, assuring the welder of obtaining satisfactory fusion and physical properties. To insure maximum density and freedom from slag pockets a satisfactory copper welding flux should be used. The tensile properties of such a joint (nonreinforced) will run between 27,000 psi and 30,000 psi, when welding hot-rolled copper averaging 32,000 psi tensile.

Fig. 17—Junction of Weld Metal and Base Metal of Weld in Fig. 16. Note the Intergranular Bond Existing Between Weld Metal and Base Metal Indicating Positive Fusion
Mag. 75 X Etchant—Chromic Acid

Table 3 shows the results obtained when forehand welding is used on various thicknesses of deoxidized copper. To shorten preheating and welding time an auxiliary torch was used, as shown. The ductility of the joint is exceptionally good, permitting in most cases free bends of 180°. Figures 5 and 6 are typical welds made on 3/8-inch copper using silicon copper rod.

Table 4 indicates the results obtained for copper pipe and tube welding. Results on the 6-inch Type L water tube are interesting in that satisfactory tensile strengths are obtained in any position of welding. All tensile strength measurements were made reinforced.

Fig. 18—Standard Test Welds on 2-Inch S.P.S. Copper and Red Brass Pipe. Bottom Sample as Originally Welded. Other Samples Pulled to Ultimate Breaking Load

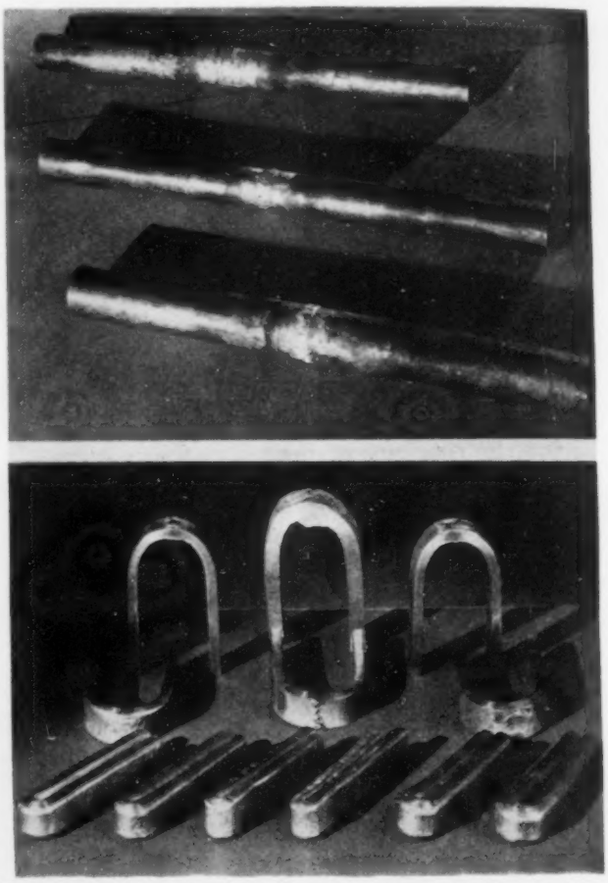


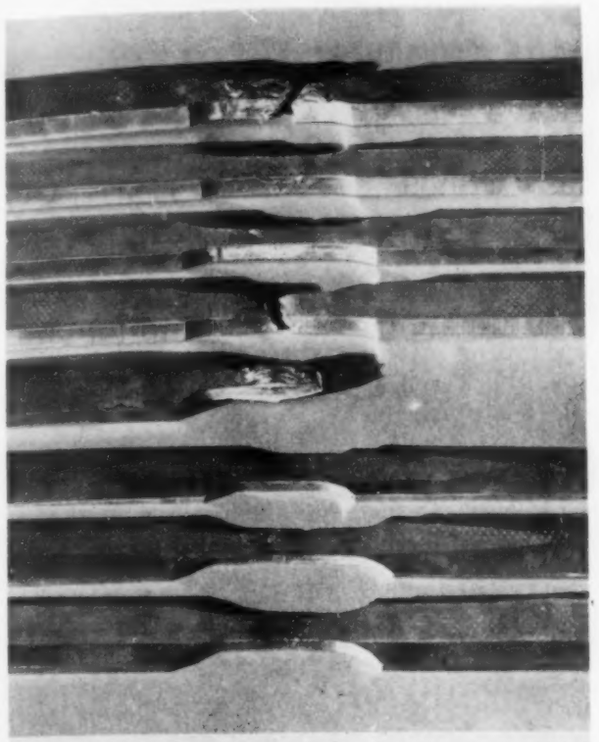
Fig. 19—Typical Free Bend and Force Bend Samples Made on Red Brass and Copper Welds. Note the Root and Face Force Bends. Free Bend Samples Bent Through 180°

Using the oxyacetylene method of welding no backup bar or chill strip is required. With the proper precaution and correct welding rod size satisfactory penetration can be obtained. Because of this result and the comparative ease of welding in all positions, this method of welding pipe and tube is recommended over the other methods.

COPPER WELDING APPLICATIONS

Successful carbon arc method of welding copper has been applied to a number of jobs. Figures 7 and 8 show the set-up and result in carbon arc welding square copper tubular bus for a right angle mitered connection. Low-tin phosphor bronze rod was used, to maintain as high

Fig. 20—Typical Tensile Strength Samples, Reinforced and Nonreinforced, for Testing Red Brass Plate Welds and Pipe Welds. All of the Above Samples, Except the Third from the Bottom, Have Been Subjected to the Tensile Test to Ultimate Breaking Load



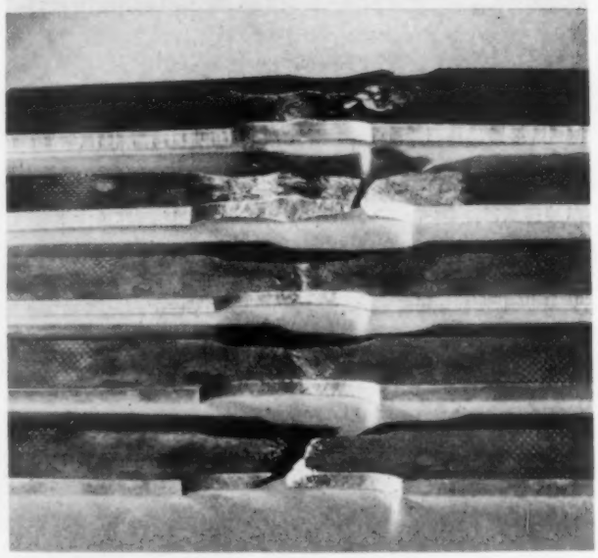


Fig. 21—Typical Tensile Strength Samples, Reinforced and Nonreinforced, for Testing Copper Plate Welds. All of the Above Samples, Except the Top Sample, Have Been Subjected to the Tensile Test to Ultimate Breaking Load

conductivity of the joint as possible. In this particular joint the outside corner was gas welded, using silicon copper. The joint is representative of approximately 80 such welds being erected in a 40,000-lb. bus installation of a 3-phase system. Figure 9 is the top portion of an all-welded copper 25-gallon range boiler. Carbon arc welding was used with a silicon bronze welding rod. The tank was subjected to a static pressure test of 200 pounds and a pulsating test of 200,000 cycles from zero to 85-lb. pressure, without any indication of any type of failure.

WELDING OF RED BRASS

Considerable welding of red brass (85% Cu-15% Zn) has been done in the past and described under the term "bronze welding." This method is the joining of red brass parts using so-called "bronze" welding rods, which are really yellow brass brazing rods, and the oxyacetylene torch. The welding of red brass using such rods should be classified as a brazing operation, and not one of welding. The term "welding" should apply only when actual fusion of the base metal occurs, as in the case of gas, carbon arc, and metal arc welding. To distinguish these methods from resistance welding, the term "fusion welding" should be used.

Red brass standard pipe has replaced yellow brass standard pipe to combat corrosion failures occurring under certain unfavorable conditions. Yellow brass is subject to dezincification failures under such conditions; the same type of failure is possible when red brass pipe is joined by "bronze welding," but the failure in this case takes place at the joint. To overcome this type of failure a welding rod containing a high percentage of copper with good welding qualities has been developed. The rod, a low-silicon bronze, contains 1.5% silicon, 0.25% zinc and the balance copper.

The handling property of the rod under the torch is very satisfactory, since the weld metal is not so fluid, which property increases the tendency to braze. By maintaining a smaller pool of weld metal under the torch closer control is obtained, resulting in more assurance of fusion to the side walls. It should be pointed out that a brazed joint, using a high copper rod, has very low tensile strength and poor ductility.

In the oxyacetylene welding of red brass pipe or plate in thicknesses from $\frac{1}{8}$ to $\frac{3}{8}$ inch incl., the edges to be joined must be beveled to a 45° single miter. Over $\frac{3}{8}$ inch in thickness best results are obtained by reducing the miter to $37\frac{1}{2}$°, or a 75° included angle. A flux specially designed for silicon bronze gas welding should be used, in the conventional manner, for best results. It is also suggested that the flux, mixed with alcohol to a thin paste, be applied with a brush to both the work and welding rods. It is also recommended that for all gages $\frac{1}{4}$ inch and heavier either a preheating torch or auxiliary torch be used.

Table 5 shows some typical results obtained by the oxyacetylene welding of red brass pipe and plate. Figures 12 and 13 are gas welds on $\frac{1}{2}$-inch red brass plate using the low silicon bronze rod.

It is entirely possible to obtain satisfactory results by the carbon arc method of welding, but it is strongly recommended that the high silicon bronze welding rod be used. This rod contains 97% copper and 3% silicon. It is designed particularly for all carbon arc welding.

Table 6 shows the results obtained in the carbon-arc welding, multiple beads, of $\frac{1}{2}$ inch thick red brass plate. The results are very satisfactory and it can be assumed that results on thinner gages would be equally good. Suggested procedure is given for other gages in this table.

For best results all gages of red brass heavier than $\frac{3}{16}$ inch should be beveled to a 45° single miter, and welded, using multiple beads. A grooved copper backup bar should be used on thicknesses under $\frac{3}{16}$ inch. Regular silicon bronze carbon arc welding flux should be used and applied as a thin alcoholic paste to the work and welding rods. Figures 16 and 17 show a carbon arc weld of $\frac{1}{2}$-inch red brass plate using the high silicon bronze rod.

Further work is needed to determine correct procedure for different gages of red brass and to observe higher heat effects on density of weld metal.

Design and Construction of Large Welded Cement Kilns*

By Carl G. Malmberg†

MANY of you, no doubt, are familiar with the construction and function of cement kilns, but for those unacquainted, I shall give a few comments on their characteristics.

Portland Cement has been produced in these United States since 1871. There are two main processes, namely, the wet and the dry process. In both processes the kiln is used to calcine the raw mix which is composed of finely pulverized limestone and shale in a liquid state known as slurry, in the wet process, and similar elements in a dry state, in the dry process. The availability of water and the properties of the raw materials have their influence on the choice of process but other factors may also resolve the method of manufacture. Owing, however, to the easier and, perhaps, cheaper control from a capital investment standpoint of the raw material, the wet method has come into more general use in recent years in this country.

In both methods of manufacture in America, the raw mix is burnt or calcined in a rotary kiln which is a long, tubular steel shell, lined with refractory bricks, which revolves slowly on its axis, the materials moving from the feed end to the hot portion by reason of the kiln's slight slope. Progressing toward the lower end, the material changes in chemical and physical condition, emerging as dark-colored, rounded masses from $^1/_{16}$ inch to 1 inch in diameter.

Carbon dioxide from the calcium carbonate in the mixture, gases of combustion and, in the wet process, moisture in the form of superheated steam escape from the kiln through an exhaust stack to the atmosphere. Chains are usually placed at the feed end of the modern, wet process kilns to assist in the transferring of the heat in the combustion gases to the slurry. As it approaches the lower section of the kiln, the dried slurry undergoes a series of reactions from which it emerges as clinker. The fuel for heating is either pulverized coal, natural gas or fuel oil blown into the kiln with a blast of air and ignited.

The tendency in late years has been to increase the length of the rotary kiln, especially in the wet process, to increase its thermal efficiency. Wet process kilns up to 450 feet long with internal diameter of from 9 feet to 12 feet are in operation in the United States. In dry process, kilns up to 175 feet in length are used in conjunction with waste heat boilers to utilize the heat contained in the high-temperature gases which issue from the kiln. But kilns up to 450 feet long are being used in the dry process with admirable success in reducing fuel consumption where the installation of numerous short kilns with waste heat boilers is not sound choice or design.

The temperature of the flame and material in the interior of a kiln is approximately 2800° F. Due to the lining of refractory bricks, this temperature is reduced to a point where, according to the best of authority, we have mean or steel plate temperature of approximately 300° F. with a probable maximum at the firing entrance of 630° F. The shell itself is in contact with the air and may be found either enclosed by a building or in the

* Presented at Annual Meeting, A. W. S., October 1940.

† Superintendent Tank and Plate Department, Allis-Chalmers Manufacturing Co., Milwaukee, Wis.

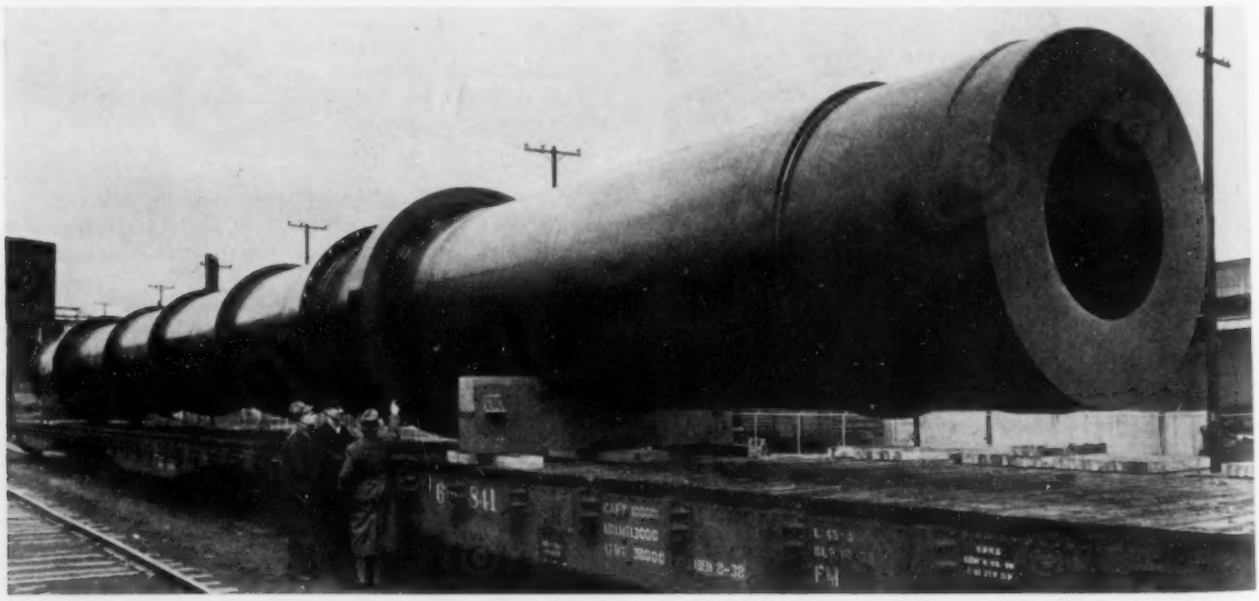
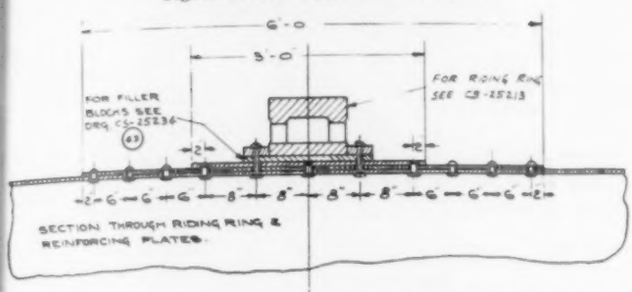


Fig. 1—Completed Kiln Ready for Shipment

Fig. 2—Riveted Type Reinforcement



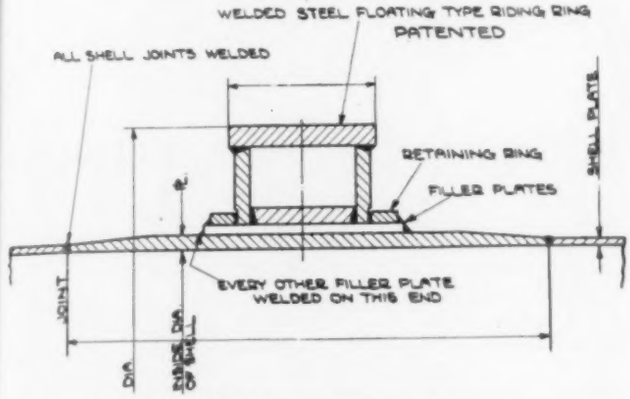


Fig. 3—Welded Type Riding Ring Course

open. Such installations in this country may be found in any latitude from the Gulf States to the Canadian Line.

Up to approximately the last decade kilns were made of steel plate joined by rivets driven by means of hydraulic or pneumatic riveters. With the advent of welding consideration was given to fabrication by this method. Several kilns, coolers and dryers have been built by us using hand welding. However, due to the high state of perfection to which riveted construction had been brought very little savings if any were noted. However, with the introduction of automatic welding the picture changed entirely and now, except for some field joints or where transportation interferes with the shipment of large sections, all our kilns are welded in entirety.

Figure 1 shows a complete kiln loaded for shipment. This kiln was 7 feet in diameter and 120 feet in length.

Kilns are not ordinarily stressed to a very high degree but they are subject to a stress reversal due to the rotation of the shell. This reversal is not very serious, however, for the speed of rotation is generally from 1 to $1^1/_2$ revolutions per minute.

The figuring of the stresses of a rotary kiln on two supports is relatively simple as it is a simple beam with overhanging ends and the reactions on the tires can be accurately determined as the weight of shell, lining and charge are known.

Where kilns are longer than 17 to 20 times the diameter it is necessary to use additional supports, usually 4 or sometimes 6 or more. In this case the figuring of the stresses is more complicated.

We allow a maximum stress in bending of 5200 to 5600 pounds per square inch making allowances for heat and joint efficiency. However, while these are normal stresses they may be greatly exceeded in actual conditions due to improper operation or quick shutdown or stoppage.

We shall now proceed to a discussion of the advantages or disadvantages of a welded kiln shell over the riveted type.

First, of course, comes the consideration of the saving in weight. Aside from the change in construction of the riding ring section which will be considered later, there are no differences in plate thickness between the welded and riveted kilns. However, there is a weight saving due to the elimination of the buttstraps and rivets. Rivets are generally estimated at 5% of the weight of a kiln and the buttstraps at about 17%. This makes a total difference of 22% but with the elimination of buttstraps, it is

Fig. 4—Shell Welded on Inside

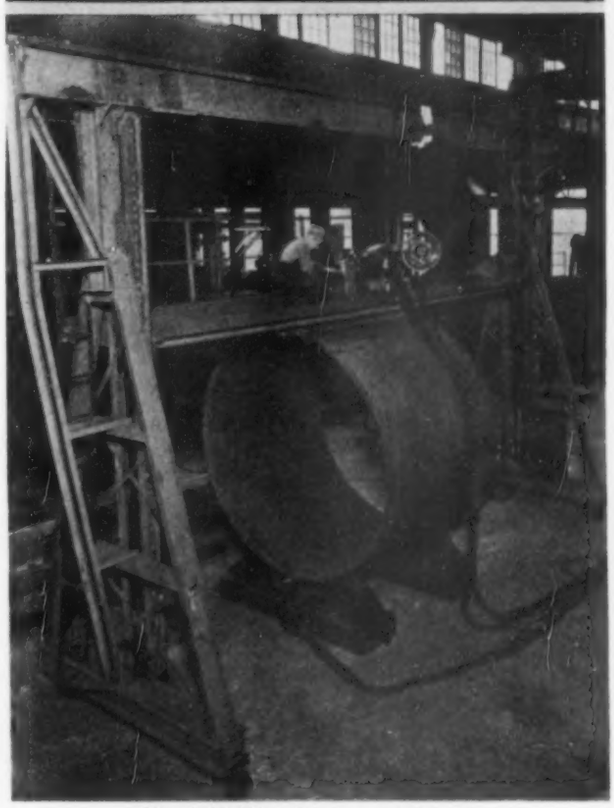


Fig. 5—Welding Seam on the Outside

necessary to weld some stiffening or anti-distortion rings. Consequently, the weight saving is approximately 15%.

I do not believe that there can be any doubt in anyone's mind as to which shell makes the best appearance.

Before taking up the question of maintenance and repair, I wish to go into the main change in design between the welded and riveted kiln. This is the aforementioned riding ring section.

Figure 2 shows the riveted type reinforcement at the riding ring. You will note that there is the inner kiln shell some 22 feet in length and then the wrappers or reinforcing plates. This type of construction calls for a large amount of punching, reaming and riveting.

Figure 3 is the welded type riding ring course. You will note that it is merely a plate approximately equal in thickness to the three plates in the previous slide, tapered at the ends to give good distribution of stresses to the adjoining thinner shell plate.

This type of construction, in addition to being simple and cheaper, has other advantages dealing with the maintenance and repair.

Due to the single thickness of plate, the rate of heat transmission is constant through the whole plate. This is not true in the three thickness riveted construction. Here we find that the inner plates become hotter than the outer with consequent buckling of the inner plate and crushing of the brick lining. This increases cost of maintenance and repair.

In addition, with this design, which is a development of our own engineers, a maximum of rigidity is obtained at the point of support eliminating all possibility of deflection of the kiln, and thus decreasing wear on the refractories that would be caused by wearing of the kiln.

Also, due to the absence of rivet heads in the inside of the welded shell, the initial cost of lining and consequential repair is less because chipping and fitting of the brick are largely eliminated.

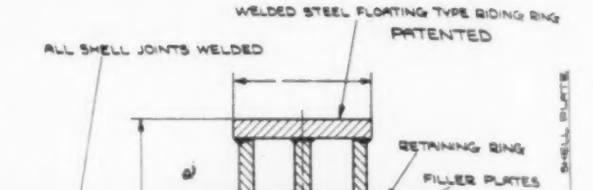


Fig. 8—Riding Ring

One other point should be considered as we compare costs, namely, engineering and layout. There is a large saving here when you consider the ease of drawing up a welded shell with its few detail parts against the riveted shell with its large amount of detailing of joints and rivets. This same factor applies in the shop where the layout man merely outlines the plate for planing.

Although punching with semi-automatic machines and hydraulic riveting have considerably lowered the cost of making and filling up holes, we have nothing in the welded shell to balance this cost. The only operation which we might say we find in the welded and not in the riveted is beveling for welding. It has always been the practice to square the plates by planing so the added cost is little when you consider it means but a few added strokes of the planer.

Now as to the methods and tools of manufacture.

The layout, as has been stated before, is essentially the same in a welded kiln as in a riveted, excepting that it is much simpler. After being laid out, the plate edges of all courses except the riding ring courses, are prepared for welding by planing in the planer shown.

As we use an automatic submerged welding process, the plate edge preparation consists of a double "V" with a substantial nose approximately $^1/_8$ plate thickness in the approximate center. No allowance is made for shrinkage, as we find with the process aforementioned that there is very little shrinkage.

After plaining, the ends of the shell plates are bent in a hydraulic press or in a shoe in a roll and then rolled.

The courses are now ready for the first welding operation, namely, the welding of the longitudinal seams.

The longitudinal seams are welded in this fashion. The joint is secured by tack welds through the middle and waster plates on the ends. The shell is then placed on the rollers and welded on the inside by means of a boom as shown in Fig. 4. For this operation the welding head travels laterally along the boom.

After welding on the inside, the shell is placed under a gantry and the seam welded on the outside as shown in Fig. 5. As before the head travels laterally along the track above the shell.

When a number of such courses have been thus prepared, they are joined together at the girth joints by tack welds. To do this efficiently we place the separate courses on a roller as shown in Fig. 6. These rollers are held in alignment on a track.

Figure 6 shows a section of the track which is approximately 120 feet in length with several of the aligning rollers in position. The rollers on the left are power driven for rotating the shell sections.

Fig. 6—Rollers for Facilitating Welding of Girth Joints

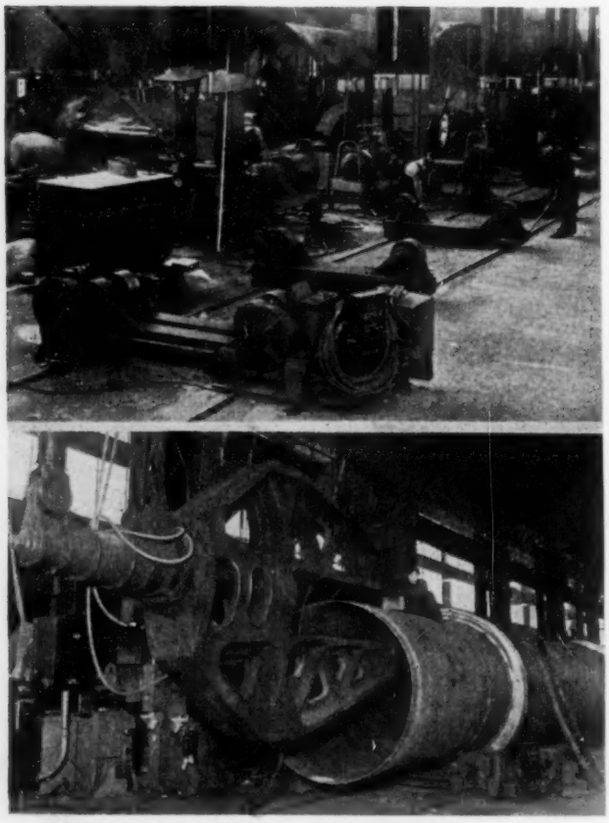


Fig. 7—Bull for Holding Shell in Place

An air-operated bull is then used to hold the shell faces flush while the tacking operating is proceeding.

Figure 7 shows the bull in place. As the shell is rotated by means of the power drive the operator clamps the shell sections into alignment by means of the bull and tacks them securely. I might mention in passing that this machine was not constructed for this job but for riveting. We have merely adapted an old tool for new work. We have found this much more successful and rapid than pulling the courses into alignment by means of straps. After tacking a number of courses together, they are welded inside by means of the boom previously shown and then outside by a gantry.

The heavier shell plates under the riding ring follow the same procedure except that instead of planing the girth seams, they are placed in a boring mill and bevel for the weld and the taper are then machined.

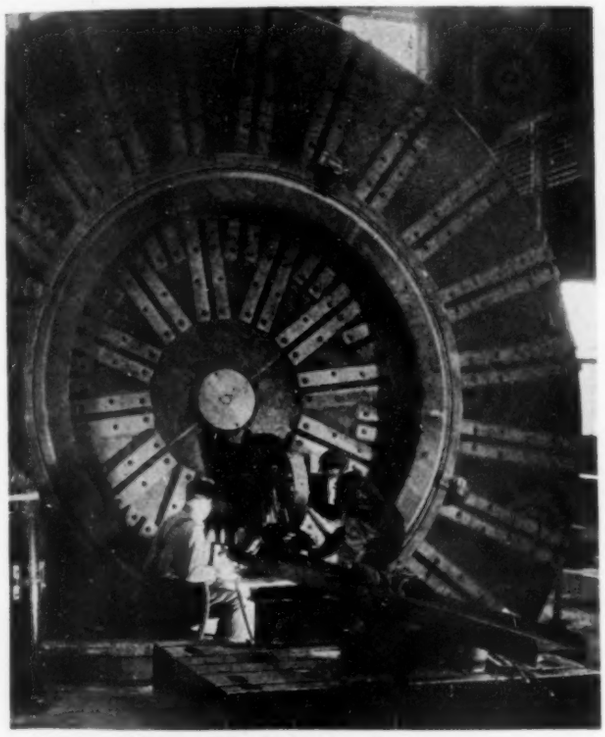


Fig. 9—Fillet Welding on Positioner

Thus the shell is welded into the lengths allowable for shipping. This may be as long as 140 feet. If the kiln shell is made of several such shipping sections, the field joints are either hand welded or riveted. Th.s depends upon erection possibilities.

The riding rings or tires are welded construction instead of cast steel as of former years. They are constructed as follows, following closely the cast steel design except that they are somewhat lighter. They are welded by a combination of hand and automatic welding. There are several types of riding rings, namely, double and triple web plain rings which carry load in the vertical direction only, and double and triple web thrust rings which carry load in two directions, that is, vertical from the weight of the shell and contents and horizontal due to the incline of the shell. There is always one thrust ring to each shell.

The riding rings are constructed as shown in Fig. 8. The inner and outer rings are rolled, welded at the joints and the outer ring bored. The center web is rolled, fitted to the inner ring and the joint welded. The fillet welds are then welded with an automatic

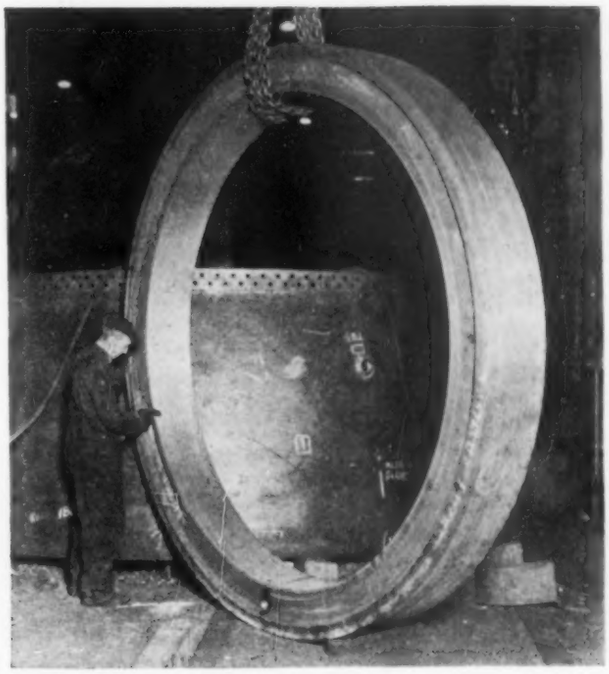


Fig. 10—Riding Ring Machined and Ready for Mounting on Shell

machine on the positioning table shown in Fig. 9.

In passing I might mention as a point of interest that this table or positioner has a capacity of 50 tons 3 feet off the table. The table diameter is 20 feet with a pit clearance of 30 feet. It is push button controlled from the welding position and is variable in speed of rotation It can be used in any positibn from the horizontal to the vertical. This picture shows it in the vertical position.

The web is next turned and shipped into the outer ring and tacked. The outer fillets are then welded as before. This weldment of inner ring, center web and outer ring is then machined for the outer webs which have previously been rolled, welded at the joints, and machined for welding. The outer webs are then placed in position and the welding completed. The complete weldment is then annealed, turned, bored and faced, and placed on the kiln shell. Here it is secured by retaining bars and filler plates all held in position by welding.

Figure 10 shows a riding ring machined and ready for mounting on shell.

In addition to the main shell parts which we have discussed various accessories such as air seals, firing hoods drive and support mechanisms are now welded.

Figure 11 shows how the cement industry has adopted this new type of construction to replace riveted sections in various riveted kilns now in service in the field.

Fig. 11—Welded Section to Replace Worn Riveted Section

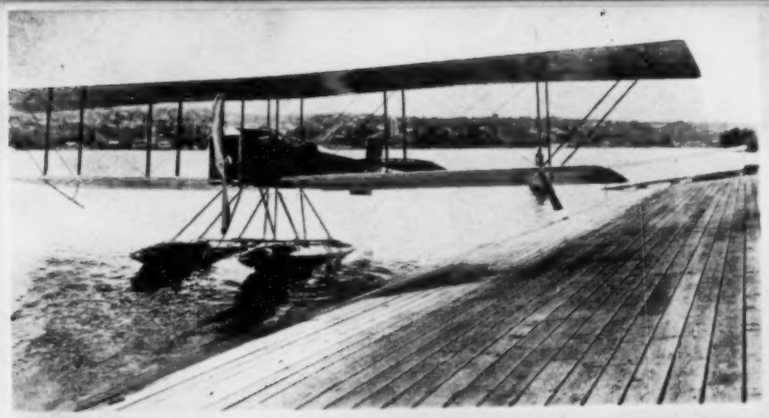


Fig. 1 (Top)
Fig. 3 (Bottom)

Fig. 2 (Top)
Fig. 4 (Bottom)

Twenty-Four-Year Evolution of Boeing Airplane Shown in Interesting Photos

By Ed C. Powers*

ACCOMPANYING photos, obtained by The James F. Lincoln Arc Welding Foundation, Cleveland, Ohio, from the Boeing Aircraft Company, Seattle, Washington, graphically illustrate the tremendous strides made in aircraft design and construction during the last 24 years.

The photos and data were supplied by the Foundation to attest the value of engineering study and research which it is stimulating by its $200,000 Industrial Progress Award Program. Four hundred fifty-eight awards, from $100 to $13,700, are offered for reports of industrial advances and improvements.

The first Boeing airplane, built in 1916 (see Fig. 1), was called the B & W. It was a two-place seaplane trainer of conventional "stick and wire" construction. With a gross weight of 26,000 pounds, a wing span of 52 feet, the plane had a maximum speed of 65 miles per hour with a 125-hp. engine.

Twenty-five Boeing Model 40-*A*'s (Fig. 2) were built in 1927 when Boeing Air Transport, a predecessor of United Air Lines, took over the operation of the Chicago-San Francisco leg of Air Mail Route No. 1. The 40-*A*'s, and the succeeding 40-*B*'s and 40-*B*4's, did yeoman service on the Chicago-San Francisco route, until they were replaced by larger planes. The 40-*A* was a single-engine biplane, powered by a 400-horsepower Pratt & Whitney Wasp, with accommodations for two passengers and 500 pounds of mail. It had a gross weight of 6000 pounds, a wing span of 44 feet, a maximum speed of 129 miles per hour. Its fuselage structure was of welded steel tubing with a covering of dural and fabric, while the wings were made of spruce, fabric-covered.

When the Boeing Model 80 (Fig. 3) was introduced to Boeing Air Transport passengers in 1928, it was hailed as the "Pioneer Pullman of the Air," because of its unprecedented achievement in travel comfort. Driving the plane were three Pratt & Whitney engines of 425 horsepower each. The gross weight was 15,274 pounds, the wing span 80 feet and the top speed 128 miles per hour. Its fuselage structure was also welded steel tubing, fabric covered.

A distinct advance in design and construction methods can be noted by comparing the giant Model 80 with the revolutionary Boeing "Monomail" (Fig. 4) introduced in 1931. The plane was America's first commercial smooth-skin, all-metal monoplane equipped with retractable landing gear. It was truly the stepping stone to the modern all-metal planes of today. Cantilever construction was used in wing and tail surfaces, eliminating all drag-producing struts and braces. The plane carried five passengers, baggage and 750 pounds of cargo. It was powered by a 575-horsepower Pratt & Whitney Hornet engine. The plane had a gross weight of 8000 pounds, a wing span of 59 feet and a maximum speed of 158 miles per hour.

The famous Boeing Model 247 (Fig. 5), produced in 1933, was developed from the "Monomail." This all-metal, low-wing, twin-engine transport established the current trend in transport design. The plane carried ten passengers and baggage, two pilots, a stewardess and cargo. With two Pratt & Whitney 550-horsepower

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Fig. 5

Fig. 6

Hornets, the 247 had a top speed of 181 miles per hour and a cruising speed of 171 miles per hour. The plane had a gross weight of 13,100 pounds, a wing span of 74 feet and a length of 51 feet.

Present culmination of the Boeing line is the Model 307 "Stratoliner," a 33-passenger, 4-engine high-altitude land transport. Two versions of this plane have just recently gone into service, Model 307 "Strato-Clippers" on Pan American Airways routes and Model 307-*B* "Stratoliners" on the transcontinental system of TWA. Powered by four Wright Cyclone engines of 1100-horsepower each, the "Stratoliner" has a top speed of 246 miles per hour and a cruising speed of 222. The plane is also equipped with the world's first commercial cabin-supercharging system, making possible comfortable flight at altitudes up to 20,000 feet. The "Stratoliner" has a gross weight of 45,000 pounds and a wing span of 107 feet.

Modern aircraft construction would be impossible without welding. This is the standard method employed by all aircraft manufacturers. Welding provides the smooth-skin construction to keep down wind resistance and also assures greatest possible structural strength with minimum weight. Research in welding and continuous experimentation in its use applied to plane structures have made possible the great strides in aviation and further study in the future will doubtless pave the way for still greater advances.

Flame Cleaning of Structural Steel*

By Frederick H. Dill†

FLAME cleaning was introduced about a year and a half ago as a method of preparing surfaces of structural steel for their initial coat of paint. It has been developed since then as a process better suited to structural fabrication than the older processes of sandblasting, chemical cleaning or mechanical cleaning. Flame cleaning utilizes relatively simple equipment but it permits the prime coat of paint to be applied on surfaces that are warm, dry and cleared of rust and unbonded mill scale. Studies of paint and of corrosion of steel have indicated that paint applied under such conditions will stand up well in service.

CLEANING PROCESSES COMPARED

The older and better-known processes for cleaning steel prior to the application of paint or other protective coatings are of interest in comparison with this new flame-cleaning process because each of them has well-established procedures and certain unique characteristics.

Sandblasting can be made to effect complete removal of scale and rust from the surfaces of structural steel, but this is accomplished at some sacrifice of other conditions that are desirable in preparation for painting. The sand or grit used is driven into the crevices of assembled pieces and it is almost impossible to remove all this "foreign material" prior to painting. It constitutes a weakness beneath the paint film because it is not bonded to the surface of the steel. If sandblasting is to be a routine operation in a fabricating plant, it must be established with permanent equipment under cover so that the dust arising from the work can be confined and so that weather will not interfere with production schedules. Such an installation must necessarily be elaborate and expensive. It will require that all pieces to be cleaned must be moved to the sandblasting location and then taken elsewhere for painting. As the pieces are usually large, cumbersome and expensive to move, the operation is likely to become a "bottleneck" in the routine of production. Thus sandblasting, which is uniquely effective in some other industries, is unsuitable for structural fabrication.

Chemical cleaning methods, such as are widely used in the automotive industries for thin materials, have not been successful as a preparation for the painting of structural steel. These methods inherently require the use of water or water solutions, and the drying of this water from the steel after it has served its cleaning purpose is a serious problem. The large size of structural members and the thickness of their component material makes it impracticable to heat them sufficiently to dry all the

* Taken from *Civil Engineering*, July 1940. Presented at the Annual Meeting, A. W. S., Cleveland, Ohio, Oct. 21 to 25, 1940.
† American Bridge Company, Ambridge, Pa.

water from their many surfaces and crevices. There is also a possibility that the cleaning solution may leave a residue on the surface of the steel which is not bonded to it and which is, therefore, an unsuitable base for the paint coat. Complete pickling of structural members would not alleviate these problems, yet it would require expensive installations of equipment and would be an expensive operation.

Mechanical cleaning, the process ordinarily used for structural steelwork, implies such operations as wire brushing and scraping, power brushing or the various methods designed to break away scale, rust and dirt by hammering. None of these procedures gets under the scale or its edges to lift it from the steel. They tend, rather, to push the scale against the steel because tools cannot be kept sharp enough to prevent them from "riding over" the edges of scale or other foreign matter on the surface of the steel. They are particularly ineffective in removing the thin films commonly found on steel rolled in some modern mills. The power tools used for mechanical cleaning are bulky and it is difficult to clean corners and complicated joints with them. Hand tools, of course, often lack the power necessary to clean effectively.

Flame cleaning of structural steel requires intense, high-temperature flames to be traversed over the surfaces to be cleaned so that they heat surface scale quickly and cause it to expand and free itself from the underlying steel before the steel is warmed enough to expand appreciably. This operation is followed by a thorough wire brushing, which breaks away any partially freed scale, dirt or rust, and removes the freed material from the surface. The flame application and the wire brushing both create a considerable amount of fine dust, and this must be swept away before paint is applied because any large amount of it would prevent the paint from wetting the surface and it might even be considered a contaminant of the paint. The heat of the flames also warms the steel and drives moisture from its surfaces and from the crevices between assembled parts. Paint applied before the steel has cooled to the temperature of the surrounding atmosphere flows easily and forms a thoroughly adherent, uniform protective coating on the steel.

The flame, in contrast to mechanical methods of cleaning, has a 'lifting action" which tends to raise exposed edges of scale and effect the removal of any that is not tightly bonded to the steel. The blistery type of scale, such as is usually found along the fillets of large beams, breaks almost completely free under the action of the flames because it is largely attached only at its edges. The free edges of scale patches or islands are curled up by the heat of the cleaning flames so that only the tightly adherent scale is left on the steel. The thin, almost glassy film which is found on many beam webs and wide plates, is not a true scale and is not much affected by the cleaning flames. It can be "pockmarked" by incipient fusion if the flames are traversed over it very slowly, but this is contrary to the process specifications and does not constitute flame cleaning. Mechanical cleaning methods, of course, are particularly ineffective in the removal of these thin films.

A primary consideration in the use of flame cleaning is its cost. It is an operation requiring the expenditure of both labor and materials and it is inevitably more expensive than the ordinary cleaning and painting procedures. The process cannot be used economically, therefore, unless it creates real savings in subsequent maintenance. Such savings are generally attained only on major structures. Flame cleaning should not be specified promiscuously as a cure-all for the painting of all kinds of structural steelwork.

FLAME CHARACTERISTICS

The engineer who requires the use of flame cleaning must understand its essential elements and also the flame characteristics which make the process possible. Experiments have shown quite clearly that high flame intensity is most essential for flame cleaning. The intensity of a flame represents its ability to heat quickly and it depends on the inherent characteristics of the fuel gas and the manner in which it is burned. High flame jet velocity and, to a lesser degree, high flame temperature are simple indices of high flame intensity.

Comparisons of acetylene, propane and hydrogen, the gases most commonly burned with oxygen, have been made to determine the value of each of them for flame cleaning. The basic characteristics of these three fuel gases and some comments on their usefulness are listed in Table 1. It was observed in making these comparisons that the flames operating at high jet velocities were definitely more effective than slower flames. This phenomenon was especially evident in tests of various types of acetylene burners which all produced flames of the same temperature. Thus the early specifications for flame cleaning which demanded minimum flame temperatures of at least 6000° F. did not adequately specify the flame characteristics necessary for flame-cleaning work. More recent specifications, which have been approved by the American Institute of Steel Construction, require that "oxyacetylene flames having an oxygen to acetylene ratio of at least one and a ratio of inner cone length to flame port diameter of at least eight" shall be used for flame cleaning.

The first of these requirements, that of an oxyacetylene flame, is made to prevent the use of gases which may burn at a high jet velocity but which do not generate enough heat to warm the steel and prevent the condensation of the moisture generated in their combustion. The second requirement insures a flame temperature which is close to the maximum attainable with any oxy-gas flame. The third requirement is designed to insure adequate flame jet velocity and, since the energy of the flame is in part proportional to the square of this velocity, this requirement is a very important one.

TYPES OF BURNERS

Some specifications for flame cleaning have prescribed the type of burners to be used, but experience with the process has indicated that such requirements are unnecessarily restrictive. It has been found, for instance, that extremely wide burners are not economical for cleaning assembled structural members because of the difficulty of manipulating them and the waste of gas which is inevitable in using them for cleaning flanges and narrow surfaces. As in the selection of paint brushes, there appears to be a practical limit to the width of burner which should be used. Comparisons between 6-, 10- and 12-inch flat burners have indicated that the 6-inch width is the most economical and serviceable for general use. This size can be easily manipulated into corners, around rivet heads and along narrow flanges without waste of gases, yet it cleans as well as a smaller burner. The efficacy of the 6-inch flat burner has been proved by using it to clean an area which contained many rivet heads, stiffeners, splice plates and fillers and then going over the surface again, after it had been wire brushed, with a round type of burner specially made for cleaning places inaccessible to other burners. This second application of the flame did not accomplish any cleaning; all removable scale and foreign matter had been cleaned off by the

Table 1—Comparisons of Acetylene, Hydrogen and Propane as Used for Flame Cleaning

Fuel Gas and Combustion Reactions	Approximate Flame Temperature ° F	Comparison of Gases as Used in Equivalent 6-Inch Flame-Cleaning Burners: Maximum Rate of Flame Propagation, Ft. per Sec.	Fuel Gas Used, Cu. Ft. per Hr.	Heat Generated, Btu. per Hr.	Water Vapor Produced by Combustion, Cu. Ft. per Hr.	Average Flame Jet Velocity, Ft. per Sec.	Remarks
Acetylene—C_2H_2 $2C_2H_2 + 5O_2 = 4CO_2 + 2H_2O + 3000$ Btu.	Max. 5600 Aver. 5400	46.5	100	150,000	100	475 to 650	Most intense and effective flames (*Increase in flame jet velocity shows marked increase in the flames' effectiveness*)
Hydrogen—H_2* $2H_2 + O_2 = 2H_2O +$ Approx. 800 Btu.	Max. 4800 Aver. 4650	29.0	200	80,000	200	270	Not as fast or as effective as acetylene (*Water vapor produced by the combustion condenses on cool steel*)
Propane—C_3H_8 $C_3H_8 + 5O_2 = 3CO_2 + 4H_2O + 2500$ Btu.	Max. 4750 Aver. 4650	12.5	80	200,000	320	160 (Counterbored flame orifices)	Slow in operation (*Flame does not heat scale without heating the steel beneath it*)

NOTE: Only 40 to 60% of the oxygen required for combustion is supplied through the burner. The remainder is taken from the surrounding atmosphere.

The maximum flame jet velocity attainable with each of these gases is approximately proportional to the maximum rate of flame propagation for the gas.

* Commercial "hydrogen" is commonly adulterated with a hydro-carbon gas in order to make its flame visible enough for adjustment.

6-inch burner. Similar demonstrations also have shown that any reapplication of the flames does not accomplish additional cleaning of the steel.

The above discussion is not intended to indicate that the 6-inch flat burner must be used for all work. Wider burners may be economical under some working conditions and there are many cases where narrower burners or round-type burners are better suited to the material to be cleaned. Recent specifications for flame cleaning require only that the individual flames of the burner "be not more than 0.15 inches center to center" and that "the number, arrangement and manipulation of the flames shall be such that all parts of the surfaces to be painted are adequately cleaned and dehydrated." The engineer can thus demand results without specifying details of their attainment.

DETAILS OF FLAME CLEANING

It is important to recognize that the cleaning flames are not suitable for drying wet surfaces because they do not supply a large concentration of heat. They are designed and arranged only for quick, intense surface heating. The flames will not burn oil, grease or paint off the steel being cleaned because of the slow rates of combustion of such substances. The flames simply flash their surface, but do not ignite them so that they will burn after the flame has passed. Even if such materials were burned there would remain an undesirable residue or ash which would have to be removed before paint could be applied. It is necessary, therefore, to wash oil, grease, paint and similar substances from the steel with suitable solvents before the surfaces are traversed by the flames.

The actual operation of the cleaning flames is relatively simple and it can be performed satisfactorily by the workmen usually employed for painting. The flames are adjusted so as to obtain the maximum length of neutral or slightly oxidizing inner cone which will stand steadily at the burner face without blowing off. The torch is held so that the flames impinge on the steel at an angle of 60° ± 15°, and the flames are traversed over the surface at a speed of 30 ± 10 ft. per min. The acute angle of attack serves to blow freed material out of the way of the flames and it avoids direct reflection of the flames, which might heat the burner and interfere with its operation.

The wire brushing which follows the application of the cleaning flames is roughly equivalent to the usual hand-cleaning preparation of steel prior to painting. Since the cleaning flames lift and free a large amount of scale, however, the brushing shows more marked results and is probably a somewhat easier operation. Old paint brushes are commonly used to sweep away the fine dust that remains after wire brushing. These are soft and close bristled and they will clean out corners better than can be done by wiping with cloth, yet they leave no fuzz or threads on the rough edges which are characteristics of structural material. Compressed air cannot be used for clearing away the freed scale and dust because, even if it is dry, the chilling resulting from its expansion may cause condensation of atmospheric moisture on the surfaces being cleaned.

Many structural members are built so that some of their surfaces cannot be flame cleaned after the member is completely assembled. Ordinary hand-cleaning methods are often adequate for such surfaces because they are not subjected to severe exposure in service. When flame cleaning is necessary, however, the surfaces which will subsequently be inaccessible should be cleaned of oil and grease, traversed by the flames and wire brushed but not painted before the member is assembled. After subsequent operations are finished, the exposed sur-

faces of the member should be flame cleaned and the previously cleaned surfaces should be wire brushed or hand scraped, as may be necessary, before the member is painted.

SUMMARY

Flame cleaning is a fairly expensive operation and it is by no means a panacea for all problems of painting structural steelwork. Steel which has been flame cleaned looks rough and almost pockmarked, especially in contrast to the uniform texture left by sandblasting or the brightened appearance which results from wire brushing. Paint applied on flame-cleaned steel creates an impression, however, of being firmly and ruggedly adherent to the steel so that it will stand up well in service. In spite of the many observations and claims of merit for the flame-cleaning process, it must be remembered that it has not been in use long enough for anyone to determine its real value in increasing the service life of paint applied to structural steel.

Operation Problems in the Small Welding Shop*

By James T. Lewis, Jr.†

THE DEFINITION AND SCOPE OF THE SMALL SHOP

IN CONSIDERING the problems of the small shop it is reasonable to assume that we are discussing the large group of little businesses that employ from one to fifty or more men, and whose work covers every conceivable application of welding and cutting from the country blacksmith shop that repairs farm implements to the highly specialized organization that builds Class I pressure vessels.

The small shop can frequently duplicate the work of its larger competitors, but because of its limited size must put up with some unavoidable handicaps. Foremost of these are lack of equipment and lack of executive and administrative personnel. It is the purpose of this paper to point out a few ways of compensating for these handicaps since there does not seem to be any way of eliminating them altogether.

CLASSIFICATION OF SMALL FABRICATING SHOPS

A welding shop, as such, may fall into one of two categories; it may be an operating department of a larger organization, essentially selling its entire output to the parent company, and having all its functions directly supervised by the parent company, or it may be what is generally termed a "jobbing shop." If the latter, its operations may be set up in one or more of the following patterns:

1. A business which is organized to furnish an engineering and design service as well as fabricating facilities and which essentially functions as the welding department for a limited group of customers, but on a contract basis and under its own supervision.
2. A business which bids on general work of almost any description and which depends largely on the customers' engineering and design.
3. The sheet metal shop.
4. The shop which specializes in repair and maintenance.
5. The shop which is organized and equipped to do field erection and construction, such as pipe lines, stacks, tanks and steel buildings.

One of the first problems to be decided by the management of the small shop is into which classification the particular shop belongs. Obviously the course of development, personnel, equipment needs and many other considerations are determined by the decision and such plans should be made early.

Time does not permit a complete examination of all the problems of all these classifications. It is the purpose of this paper to discuss a few salient problems which will probably be common to all welding and cutting shops, although the background of the argument is based on experience gained in both the welding department of a large company and in a small shop which specializes in the construction of machinery parts for a limited number of customers. We wish merely to point out a few problems which continually arise and suggest at least one method of meeting each of them. For clarity we have separated the discussion of welding from the discussion of cutting, although practically every shop performs both operations.

Welding Problems

The principal welding problems in so far as operation and supervision are concerned can be grouped as follows:

1. Design.
2. Personnel—training, qualification, etc.
3. Use of special equipment.
4. Assembly jigs and fixtures.

Design Problems

One of the foremost problems of the welding shop is the procuring (or executing) of adequate drawings and details of the parts to be made. The persons responsible for the fabrication of the part must determine surface requirements, joint design, machinability, loading, special weld requirements of oil or gas tightness and finally whether any special treatment such as normalizing stress relief or peening is required.

The customer's drawings must be carefully examined with an eye to adapting the work to the available equipment wherever possible. Customer cooperation is easy to obtain if there are any real improvements to be gained by a few changes in specifications. A good basic rule is to assume that the customer's drawing can be improved upon and then go ahead and prove it.

To illustrate, a drawing may call for corner welding of plates, while a heavy press brake can form the same

* Presented at the Annual Meeting, A. W. S., Cleveland, Ohio, Oct. 21 to 25, 1940.

† President, Lewis Welding and Engineering Corp., Cleveland.

section in a fraction of the time required for welding. Steel castings may be included in an assembly but a little ingenuity may provide a fabricated substitute. Frequently, if a hydraulic press or bulldozer is available, by using simple and inexpensive dies, relatively complex shapes can be produced at a lower cost than patterns, core boxes and castings. As a general consideration, use plates wherever possible, rolled shapes where desirable and castings only when special analysis or proved economy leaves no other alternative.

Personnel

There are two accepted methods of training operators. One way is to take new graduates of recognized welding schools and by constant guidance and supervision train them in your methods of working. This method has the distinct advantage of reducing the training period during which the man is a financial liability. On the other hand, depending on the school at which the novice has received his preliminary instruction, the difficulties of "unlearning" methods and practices which are not compatible with your own shop procedures may offset the apparent financial advantage of this method.

The other method of training an operator is to bring him right into the shop organization without any previous training in welding. A young man with some shop experience and the ability to read the average shop drawing makes an excellent candidate. Giving him a job as a tacker (and he can learn to tack in a day or two), preferably working with an experienced assembly mechanic, will instill confidence in him and teach him the general character of the work in a short time. At this point, choice of his senior is of the utmost importance. He should be put to work with a man who understands the purpose of the novice's work and who is eager to help him learn his job. Many an oldster has had the notion that the apprentice is an understudy and refuses to tell him anything, thinking thus to save his own job. Whoever is responsible for apprentice training should constantly guard against this circumstance. As time goes on, give your apprentice every opportunity to practice. After his time is up, and there are machines available, turn him loose on the scrap pile. The cost of welding rod and power for his practicing is a small price to pay for the skill which you can encourage him to develop. Keep a constant track of his development and give him actual production work to do as soon as he is able to handle it. As his skill develops, give him more and more difficult work to do. If you have the right man, one who is willing to go through his apprentice period painstakingly and thoroughly, you will find that he will become a contributing part of your organization within a relatively short time.

In the grading of welding operators for pay schedules, it is our opinion that too much stress is laid on standard qualification tests. What a man can do is not of nearly so much importance as what he does do. Here we refer entirely to men working on hourly rates and not piecework or bonus schedules. Since each shop has its own production problems, it is our opinion that it is a function of supervision to give each man the work he can do to best advantage, wherever possible, and that the relative volume of that work which is acceptable should be the determining factor. In other words, the fact that a man could make a perfect multi-pass Class I butt weld would not be a good measure of his producing ability if all his work were single-pass fillet welds in light material.

Use of Special Equipment

The subject of special equipment in the welding shop is one that cannot be given too much attention by management. The use of press brakes, hydraulic presses, bending rolls and similar tools will open up entirely new fields for their owners. From a competitive standpoint they are obviously an advantage since much of the welder's work can be simplified or made less difficult by the use of tools. But we feel that the more important aspect of their utility arises from the advantages to the designer. The ingenious use of the bending brake, for example, may make possible the creation of numbers of welded assemblies which would be otherwise out of the question from the standpoint of economy.

The shop that has the tools will probably have the work, and the small shop which plans to grow would do well to have a well-planned equipment procurement program to be completed as fast as finances permit.

Assembly Jigs and Fixtures

Many small shops find that a large proportion of their work is repetitive. The smallest machine shop will equip itself with simple jigs and fixtures if a reasonable number of pieces are to be made to the same drawings and specifications. The welding shop that does not follow suit is missing a fine opportunity to make some real economies and frequently to hold the finished pieces within closer dimensional limits.

Typical fixtures do not need to be elaborate. Many times a flat plate with simple stops conveniently located will suffice. If the various pieces are to be located from previously drilled holes, round pins are most convenient. If straight edges give the critical dimensions, round or square stops may be indicated.

In the short time allotted to this discussion we cannot dwell very long on this subject. We cannot help but urge, however, that it is a subject that deserves a great deal of attention from the organization, from the estimator to the welder operator.

Appearance

The current trend toward streamlining and the elimination of sharp corners is strongly apparent in the welding field. Smooth-flowing surfaces and generous radii in fillets and corners do much to improve the general appearance of the finished assembly. Whereas much is to be said for the point that welding should not be disguised to look like casting, on the other hand consistency in appearance is desirable and the portable sander or surface grinder is a pretty valuable tool. Unsightly reinforcement of butt welds where they are not necessary for mechanical strength, and fillet stitch-welding on exterior surfaces where they are readily apparent do not make for the appearance of good workmanship. Consider the utility of the part being made and if appearance is of any consideration, put enough time in the estimate to grind or sandblast to a proper finish.

Nothing is much more unsightly than welds with slag still adhering. Aside from appearance, all welds should have the slag removed as a matter of operator discipline. An uncleaned weld is to us the earmark of poor inspection, since we have never solved the problem of crack detecting through a slag coating.

Cutting Problems

In this discussion, in so far as the use of oxyacetylene cutting equipment is concerned, we wish to briefly comment on the following topics:

1. Gas supply.
2. Automatic equipment and templates.
3. Care of equipment.
4. Torch cutting versus shearing.

Manifolds and Permanent Piping

Even the smallest shop would do well to consider carefully the installation of manifolds and permanent piping for the cutting gases, but most particularly for the oxygen, since it represents by far the larger volume. A personal study of the cylinder handling problem in a medium-sized shop indicated a cost of approximately $0.15 per cylinder, or approximately 7% of the total cost of the gas. Other sources have reported costs as high as 30¢ per cylinder. This actual cost is all labor and takes no account of the operating losses arising from idle time when cylinders are being changed.

A centrally located manifold, preferably set up at a spot convenient to receiving and returning cylinders, will cut this handling cost to a minimum. Furthermore, a generous size of manifold assures infrequent interruptions of supply and infrequent changing of cylinders with obvious attendant cost reductions. It is probable that any shop that has three or more men performing oxyacetylene operations can successfully install a permanent piping system that will really show substantial savings.

Automatic Cutting Equipment

The use of automatic gas-cutting equipment has opened up many of the fields of production now served by the welding shop. Since a large proportion of the welder's work is actually in direct competition with the products of the iron and steel foundry, it is necessary for the welding shop to be able to produce shapes of extreme complexity. Many excellent articles have been written on this subject and it is not our intention to elaborate on the subject at this time. The important point is to remember that the cutting machine should be considered in the same way as any other tool, with the fact in mind that the investment is relatively low when compared with most production equipment. The volume of completed work is high per dollar invested since the availability of the tool appreciably broadens the scope of the shop.

For the small shop with limited capital, we recommend the simplest form of portable automatic machine which can cut straight edges and circles. This machine can be purchased for less than $150 and will prove to be an invaluable piece of equipment. At the other end of the scale are the large table-type machines which can be used for repetitive reproduction from templates, small quantity production by hand tracing full-scale drawings, and cutting straight lines and circles. The individual shop must determine its own needs, however, and the equipment manufacturers can give the best advice on particular requirements. In our own plant we use one portable and two table-type machines. We find all of them in continual use and all indispensable even though we do not make a business of furnishing so-called shape cut parts, but use the equipment only in the preparation of pieces prior to assembly into larger structures.

The use of templates with the cutting machines should be analyzed in exactly the same way as the jig and fixture problem. If there are a lot of parts to be made to the same pattern, and accuracy is of great importance, use templates. If not, hand tracing is a good method and a trained operator can turn out very presentable work this way.

Care of Equipment

Like any other tools, the oxyacetylene equipment should be cared for meticulously. After all, the only secret to good cutting is the proper combination of tip size, cutting speed and gas pressures, and a dirty or worn tip will destroy all those ratios. The best cleaning method is to use the exact drill size recommended by the manufacturer for each tip size, and keep the passages clear with the right size drill only.

A common tendency of torch operators, in both manual and machine cutting, is to use too high pressures. Both costs and quality suffer and the operators must be taught to use the lowest pressures that will do the work.

When you consider that torch cutting is no more than a violent chemical reaction taking place in a region confined only by the accuracy of the stream of oxygen, the importance of perfect tips and correct pressures is very apparent.

Torch Cutting Versus Shearing

Much has been said on the subject of torch cutting versus shearing. Again it is largely a matter of arithmetic since modern squaring shears give good square edges with little drag-down and minimum twist in plates of $^1/_2$ inch and under in thickness.

A good squaring shear which will handle ten or twelve feet of $^1/_2$-inch plate will cost about $7000 installed and ready to run. The straight-line burning equipment will cost $150. The shear takes little power but costs a good deal to buy. The cutting machine represents little investment but high operating costs. Thus, the answer to the problem becomes one that each shop must decide on its own financial capacity and its own volume of work for the tool.

CONCLUSION

In conclusion, it is to be emphasized that welding is a field for skilled mechanics. A good welder cannot learn his trade in 30 days in a welding school, nor can he learn it in 30 weeks. Thirty months should make a reliable operator if he has good supervision and assistance.

The art of fabrication by welding far transcends the melting of welding rods by arc or acetylene flame. While we cannot expect all welding operators to be metallurgists, they should understand, in general, what happens when the weld metal is deposited; how the various types of rod perform under various conditions; what constitutes good workmanship. They should be capable of correcting disadvantageous conditions without complaining of "poor ground," "bad fit-up," or "wrong kind of rod."

Probably the most useful men are mechanics who can weld. By rotating work the small shop organization becomes more flexible and develops men of broader experience who can fill in where they are needed most. If the press operators can weld and the assembly mechanics can also run the burning machines and do layout work, for example, changing schedules do not require frequent personnel adjustment and long hours for some men and short hours for others—a condition which always breeds discontent.

Someone has defined skill as the ability to do the best job in the quickest and cheapest way and our experience gives us no indication but that this rule applies in the welding shop the same as anywhere else.

Welding Metallurgy

VOLUME II

By O. H. HENRY and G. E. CLAUSSEN

A series of lectures prepared for presentation in a fundamental course of metallurgy and metallography at Polytechnic Institute of Brooklyn under the joint auspices of the Institute and the New York Section of the AMERICAN WELDING SOCIETY. To be published serially in The Welding Journal. The lectures are reproduced in attractive booklet form, copiously illustrated—357 pages—with imitation black leather covers. Volume 1 consists of the first series of 10 lectures given by the New York Section in cooperation with the Polytechnic Institute of Brooklyn last year. Volume 2 includes the series of lectures given this year. The price of the book containing both volumes is $1.50 per copy. Special prices can be arranged for quantity lots of 50 or more.

Part III—Brittleness and Cracking

Brittleness and cracking are two major welding difficulties which the metallurgist is called upon to diagnose and correct. Both difficulties will be familiar to those who have studied Vol. I (see Parts V and VII). We can define both at once by saying that brittleness is the condition in which cracks readily form. Before discussing cracks, therefore, we will review what is known about brittleness in welds. Neither cracks nor brittleness are found ordinarily in welds, yet it is idle to imagine that we can avoid them consistently without knowing what they are and how they come about.

What is "brittleness?" A brittle weld fractures without deformation. To illustrate brittleness and its opposites, bend $^1/_8$-in. rods of glass, soft rubber, lead, and soft steel. The glass rod snaps; it behaves in a brittle fashion. The soft rubber rod can be bent double, but springs back to its original shape; it is elastic. The lead rod is bent double easily and remains bent; it is weak and ductile. Likewise, the soft steel rod can be bent double and remains bent, but it requires more force to bend the steel than the lead. Compared with lead, the soft steel is tough as well as ductile. Yet the three materials that can be bent easily at room temperature can be made to break in a brittle fashion under some condition, while the glass rod, if bent at a red heat, does not snap, but behaves like taffy.

Although we have no difficulty in stating that, in bending, glass is brittle and lead is not at room temperature, it is more difficult to decide whether or not different steels are brittle. In the tensile test with load in one direction, an elongation at fracture of 20% in 2 in. is characteristic of ductile weld metal; 5% would be brittle. Yet bridge wire with 5% elongation is ductile, while with 2% it would be classed as brittle. We see that there is no absolute value of tensile ductility below which all materials can be said to be brittle and above which they can be said to be not brittle. For purposes of discussion, however, we can say that a material is brittle if it breaks without appreciable deformation, Fig. 16.

It is disconcerting to find that a metal which deforms greatly before fracture when the tensile load is applied in one direction, does not deform to so great an extent if

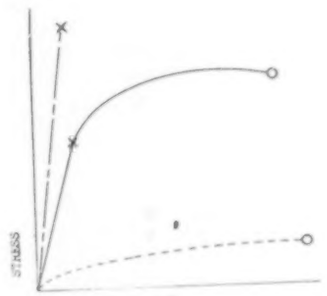


Fig. 16—Stress-Strain Diagrams in the Tensile Test

If fracture occurs at X before the specimen has elongated permanently to any appreciable extent, it is said to be in the "brittle" condition. Metal deforming considerably before fracture at O is said to be ductile, regardless of the magnitude of the stress at fracture

tensile stress is applied in two directions at right angles, as in the shell of a boiler, Fig. 17. The steam inside the boiler tends to blow off the ends. They are held to the shell because the steel can withstand the tensile stress *A-A* without failure. The steam also tends to expand the diameter of the shell, which causes tensile stress *B-B* at right angles to *A-A*. When the shell at last ruptures, under excessive steam pressure, we examine the fracture, and find that there has been little deformation, not more than 2 to 5%. Yet a specimen cut from the shell develops an elongation in the tension test of 20%. The decrease in elongation when two tensile stresses are applied at right angles to each other suggests that the steel cannot contract to so great an extent as it does when tensile stress is applied in only one direction. If the second stress is compressive, instead of tensile, the contraction of the steel under the tensile load is favored, with the result that the deformation is unusually large before fracture

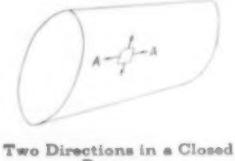


Fig. 17—Stress Acts in Two Directions in a Closed Drum Under Internal Pressure

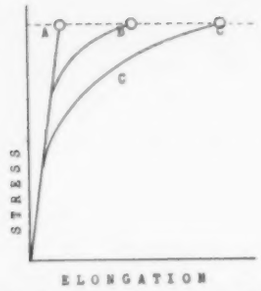


Fig. 18—Effect of Multi-Axial Tensile Stress on Elongation at Fracture (Schematic)

O = Fracture
A = Tensile stress in three directions
B = Tensile stress in two directions
C = Tensile stress in one direction

occurs. If tensile stresses in two directions reduce the deformation which a material can undergo before fracture, Fig. 18, tensile stresses in three directions still further reduce the deformation. The embrittling effect of notches in a metal is caused by the bi-axial and tri-axial tensile stresses generally created in their vicinity on the application of load. Comparing Fig. 18 with Fig. 16, we see that a mild steel which behaves in a brittle fashion when tensile stress is applied in three directions, may behave as a ductile material in the tensile test with load in only one direction.

Why cannot the steel deform so much when tensile stress is in two directions? The answer is to be found in the process of slip along crystal planes by which metals deform (see Part V of Vol. I). When equal tensile stresses act in three directions at right angles at once—a condition which rarely occurs—slip is prevented completely, because no plane of atoms is able to move in the opposite direction from the plane above or below it. When slip is prevented from occurring, the material fractures by one plane of atoms losing its grip on an adjacent plane.

Five Ways to Prevent Slip

Brittleness thus becomes a question of slip. We have seen that slip may be prevented by bi-axial or tri-axial tensile stress. There are four other ways of preventing slip.

1. The first way to prevent slip is absurdly simple. Test a material in which slip has been forced to occur previously on every possible slip plane, for example, by cold working (cold rolling, cold hammering, etc). When tensile stress is applied, no planes can slip and the metal can undergo no permanent deformation before brittle fracture. Brittle welds from this source sometimes are found in forge-welded wrought iron. The smith knows that he should continue to hammer the weld below a white heat to refine the grain size. If, however, he carelessly hammers the weld at too low temperature, he cold works the metal and reduces its capacity for subsequent deformation.

2. Slip can be prevented by wedges inserted at intervals along the planes of atoms. Like emery between polished gage blocks, the wedges prevent the planes of atoms from sliding over each other. The wedges are the crystals which can be induced to grow at myriads of points in a crystal of a different sort (see Part IV of Vol. I). A good example of slip prevention by tiny crystals is martensite, described in Part IX of Vol. I. When austenite is cooled so rapidly that it does not transform to pearlite, it transforms at a lower temperature to martensite, the transformation involving a change in crystal structure and appearance of extremely small crystals of carbon or iron carbide. Thus some of the planes of atoms in the austenite are jumbled into another form, this process itself tending to prevent slip. At the same time, another type of crystal, carbon or iron carbide, appears and blocks still further any slip along planes of atoms. Consequently, martensite in the higher-carbon steels at any rate provides practically no planes for slip, and fractures without appreciable deformation under load.

Martensite in the heat-affected zone of an alloy-steel weld may or may not cause the joint as a whole to be brittle, Fig. 19. The stress-strain curves of the three essential parts of the joint are shown at (*a*). If the stress is applied perpendicular to the weld, Fig. 19 (*b*), the stress cannot rise above the yield strength of weld metal and base metal, without deformation of both. Should the stress be applied parallel to the weld, Fig. 19 (*c*), the conditions are entirely different. As the strain increases, the stress rapidly rises in the martensitic zone, corresponding to the stress-strain curve in Fig. 19 (*a*). At a small elongation the martensitic zone ruptures; that is, it cracks. Once the crack appears, it acts as a notch with the accompanying multi-axial stresses, and may spread with the velocity of a pistol shot through the remainder of the cross section.

3. The third basic way in which slip can be prevented is by means of films of brittle, weak material surrounding the crystal grains of another more ductile metal. We know that a sharp rap on a bathtub causes the enamel to crack without affecting the steel. What would happen if every grain of steel were surrounded by a film of enamel, which is not a very different material from glass or slag? Being unable to deform under stress the enamel films would crack at a low stress. The grains of steel, having nothing to hold them together, fall apart once the cementing film has broken.

There are many examples of the embrittlement of metals by weak or brittle films of impurities. Bismuth in minute percentages forms films in copper, which loses its characteristic ductility. Repeated stress annealing of welded chains produces films of cementite around the grains of ferrite and the chain becomes embrittled. Iron sulphide, being the last material to solidify in improperly refined steel castings, exists as films which reduce the ductility to extraordinarily low values.

4. The final way to prevent slip is to affect the basic properties of the metal so that instead of the planes of atoms slipping under stress, they tend to lose their grip on each other. The situation may be realized by sliding

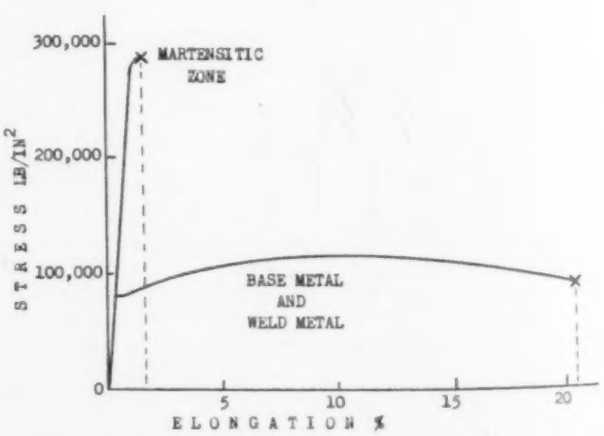


Fig. 19 (a)—Stress-Strain Diagram Showing a Ductile Base Metal (and Weld Metal) and a Brittle Heat-Affected Zone

X = Fracture

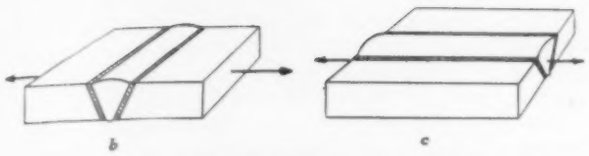


Fig. 19 (*b*)—Single-Layer Butt Weld Made with a Mild Steel Electrode in High-Tensile, Medium-Carbon Steel

Shaded area is martensitic heat-affected zone. When stressed transversely, as shown by the arrows, the weld metal and unaffected base metal deform without causing cracks in the shaded zone

Fig. 19 (*c*)—Same as (*d*) But Stressed in the Direction of the Weld

The martensitic zone is forced to deform and soon cracks, as shown in (*a*)

two gage blocks over each other. With an oil film between the blocks and perfectly plane, smooth surfaces, it is easier to move the blocks by sliding one on the other than by pulling them apart. By removing the oil film or by spoiling the polish on the contacting surfaces, we can make it easier to pull the blocks apart than to cause them to slide over each other. Although similar changes in ease of sliding and pulling apart are known to be undergone by metals, we have little control over them. The changes are governed by the ratio of tensile strength to shear strength. If the ratio exceeds 2, slip occurs; with a ratio less than 2, the planes of atoms tend to pull apart without slip, and the metal fractures in a brittle fashion. An example is the embrittlement of notched mild steel weld metal at about −100° F. Steel which is tough in the presence of a notch at room temperature may break like glass below −100° F., the change in behavior being related to a strange change in ratio of tensile to shear strength.

Brittleness in Steel

The five ways in which brittleness may be caused are: (1) bi-axial or tri-axial tensile stress (notches); (2) cold work (no slip planes available); (3) precipitation (wedges in the available slip planes); (4) intergranular films which rupture before slip occurs in the grains themselves; (5) low ratio of tensile to shear strength. We are now prepared to understand all the brittle conditions in which steel may exist, starting at the highest temperatures.

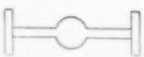


Fig. 20 (*a*)—Specimen Used to Demonstrate Cracks in Solidifying Metal

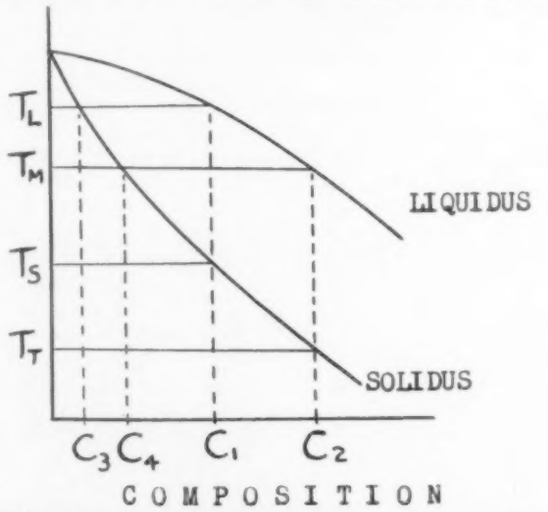


Fig. 20 (*b*)—Diagram Showing That Liquid May Be Present in a Rapidly Cooling Alloy at Temperatures Below the Solidus Shown in Equilibrium Diagrams

C_1 = Original composition of melt
T_L = Temperature of the liquidus for melt of composition C_1
C_3 solidifies at T_L. If at the lower temperature, T_M, the crystals of C_3 had not reacted to form crystals of composition C_4 owing to rapid cooling, then the remainder of the melt solidifies as if its original composition were C_3 instead of C_1, for the reason that crystals C_3 are as if removed from the solidifying mass. C_2 completes solidification at T_T, which is below the solidus temperature T_S for the alloy

Tears

The first temperature range in which brittle behavior is exhibited by steel is the end of the solidification range (see first section of Part VII of Vol. I). The last remnants of liquid remain between the grains of steel; the grains have not yet grown completely together. The grains resemble logs in a sawmill pond. They can be pulled about easily and separated from each other, yet once the water freezes, the logs are cemented firmly together. If the steel is pulled just before the last liquid solidifies, it fails at absurdly low stresses and with scarcely any elongation. Fig. 20 (*a*) is a specimen sometimes used by steel foundrymen to determine the tendency of their steel to tears, which is the name given to the cracks which occur in the steel when solidification has practically finished. When the casting is cooling, the bulbous center portion cools more slowly than the rest. The shrinkage of the remainder of the casting causes hot tears in the bulge.

The temperature of the steel generally is below the solidus temperature when the cracking occurs. There is no difficulty in understanding that the liquid remains in the steel below the temperature at which the equilibrium diagram leads us to expect. In the first place, the steel is cooling fairly rapidly and it is difficult to measure the temperature precisely at the hottest part of the bulbous portion. In the second place, the fairly rapid cooling prevents attainment of equilibrium, as shown in Fig. 20 (*b*). Third, the steel may contain impurities, particularly sulphur, which may lower the melting point. Steel foundrymen know that compounds and eutectics of iron, aluminum, and manganese, with oxygen and sulphur may form phases of low or high melting points depending upon relatively slight changes in composition, which they take care to adjust properly.

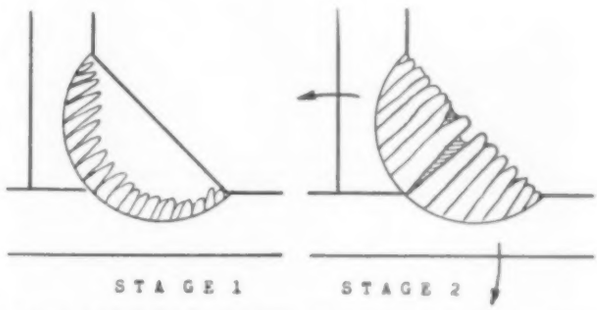


Fig. 20 (*c*)—Two Stages in the Freezing of a Fillet Weld, Showing Narrow Spaces Partly Filled with Shrinking Liquid (Shaded)

Arrows indicate the directions of shrinkage stresses, which are opposite to the directions of shrinkage distortions

There is a close similarity between Fig. 20 (*a*) and a butt or fillet weld, Fig. 20 (*c*). The bulb in Fig. 20 (*a*) corresponds to the throat of the fillet, which is the thickest part of the fillet and the last to freeze. While it is cooling the solid weld metal welded to the walls of the fillet is contracting, movement being in the direction of the arrows. Unless the plates are thin, they will offer sufficient restraint to pull apart the crystals at the throat, which are separated by a film of liquid metal of zero tensile strength during the last moments of freezing. In this way hot cracks or tears may arise in welds. The

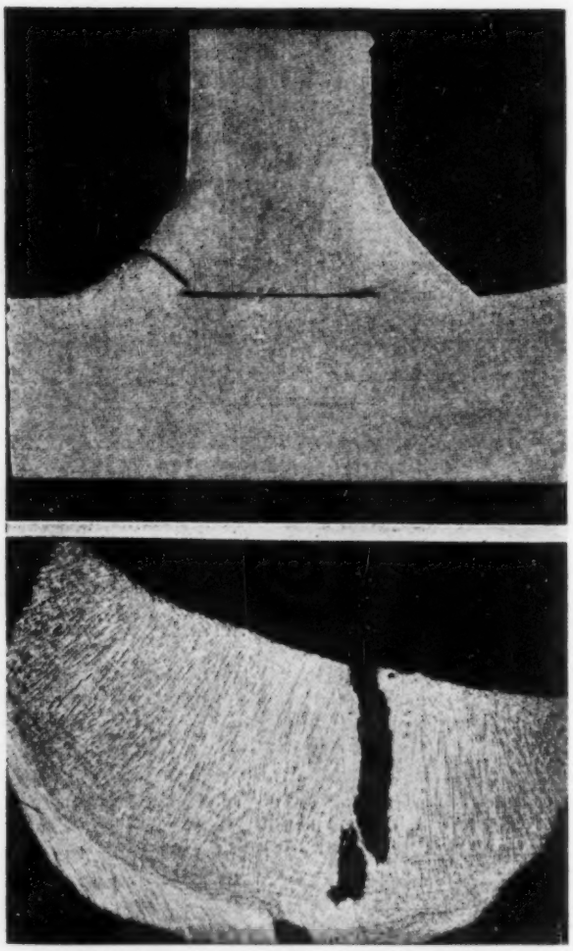


Fig. 20 (*d*)—Cracks in Fillet Welds. (Helin and Svantesson)
(Upper) Natural size
(Lower) Low magnification, showing dendrites in weld metal

Fig. 20 (*d*)(*Continued*)
Interdendritic impurities in a fillet weld (high magnification)

crack, Fig. 20 (*d*), is a gap through the center of the weld between two adjacent dendrites that have shrunk away from each other before the liquid between them was able to solidify and to weld them together.

Hot cracks in weld metal are not frequently observed, because electrode manufacturers realize that any impurities, such as slag, accentuate the range in which liquid metal or slag exists between the grains. Hot cracks, in other words, occur particularly when the weld metal contains a good deal of slag. Furthermore, the weld is less able to resist contraction when the throat is small than when the throat is large. Since hot cracks, when they are found, always are in the root bead, it is wise to avoid a small root bead if cracks are feared. Increasing the rigidity of the joint by using steel of high tensile strength tends to favor weld cracks, if only for the reason that the weld becomes less ductile through pick-up of alloying elements from the plate.

Red Shortness

Red shortness is the brittleness that appears at about 1000–1200° C. A bar of steel that is not red short can be bent double over an anvil at 1000–1200° C. without fracture. If the steel is red short, light hammer blows will crack it and split it apart. Below 1000° C. and above an upper temperature that is in the vicinity of 1200° C. the steel does not exhibit red shortness. When the red short steel is examined under the microscope, each grain is found to be surrounded by a film of yellow iron sulphide, FeS, Fig. 21.

It is easy to secure weld metal containing these films by depositing the electrode through a layer of iron sulphide The sulphide has the undesirable property of forming a eutectic with iron that does not freeze until 985° C. is reached, about 500° C. below the freezing range of steel. When steel containing films of iron sulphide is heated above 985° C. the sulphide eutectic melts, forming a film around each grain. Under hammer blows the grains are not welded to each other and so fall apart in brittle fashion. If the temperature is raised to 1200° C. or so, the sulphide collects in globules, instead of remaining dispersed as film. In globular form the eutectic no longer surrounds each grain and the steel can be forged without cracking.

The corrective for hot shortness is manganese. Any manganese added to steel tends at once to combine with the sulphur to form manganese sulphide, MnS. To combine completely with the sulphur, at least $1^3/_4$ parts of Mn should be added to the steel for every part of sulphur, and it is customary to add a larger proportion to ensure absence of hot shortness. Additional manganese is desirable to prevent oxygen in the steel from combining with all the manganese leaving none to form MnS. In welding, oxidation of Mn is favored by a long arc and by rusty, scaly scarves. Once the manganese is oxidized to MnO, it cannot form MnS. Any sulphur in the weld metal then is free to form the undesirable FeS. Weld metal containing FeS is likely to crack during hot peening. Precautions against red shortness are called for if high-sulphur, free machining steels are to be welded and the welds are peened.

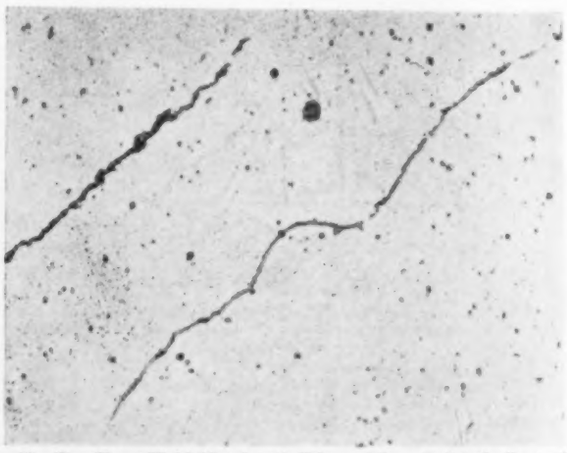


Fig. 21—Hot-Short Weld Metal with Films of Iron Sulphide Separating the Dendrites. (Helin and Svantesson, High Magnification)

Critical Range

When a steel cools through the critical range the austenite grains change to ferrite and cementite. There is a complete rearrangement of grain boundaries. The change in crystal structure in the critical range involves movement of planes of atoms in a way analogous to the effect of hot work. While the planes are shifting about, it is found that the steel is rather weaker but more ductile than just above or below the critical range. There is no likelihood of brittleness, therefore, while a steel is cooling through its critical range.

Secondary Brittleness

When a steel exhibits secondary brittleness—and steels of all carbon contents seem afflicted with it—the elongation in a short-time tensile test is a little lower at 500° C., the temperature of secondary brittleness, than at temperatures somewhat higher or lower. Corresponding with the decrease in ductility there is an increase in tensile strength. The changes are on a small scale and they appear to be of no significance for welds. It will be recalled that in the discussion on fish eyes toward the end of Part V of Vol. I, the view was repeated that hydrogen, dissolved in the steel at high temperatures, came out of solution at lower temperatures and built up pressure within the steel. A similar hypothesis has been successful in explaining cracks in some types of rails; the hydrogen pressure acts inside the steel and, at the temperature of secondary brittleness, is able to cause brittle cracks in its effort to expand and to escape from the steel. Although the hydrogen theory of fish eyes has not received much support, neither has the theory that fish eyes occurred only in weld metal deposited by one class of covered electrodes. It appears that fish eyes may occur in deposits from other types of electrodes, that they start at inclusions or in regions of coarse-grain structure, and that they are prevented by stress-relief heat treatment.

Blue Brittleness

Like secondary brittleness, blue brittleness is the reduced ductility exhibited by steels in a characteristic range of temperatures, namely: about 300° C. Again the reduction in ductility at 300° C. is accompanied by unexpectedly high strength. So far as experience extends, blue brittleness has no significance for welding. Both secondary brittleness and blue brittleness are believed to be brought about by the precipitation of crystals of some sort, as yet unknown, in the grains of which the steel is composed.

Another form of brittleness that may be mentioned is temper brittleness, which is confined to some alloy steels containing 0.35–0.55% C. Of course, the steels are seldom welded. Nevertheless, the various "brittle conditions" of steel often are used too loosely to explain difficulties with which they have not the faintest relationship. Such is the case with temper brittleness. According to the correct meaning of the term, a steel that exhibits temper brittleness has unexpectedly low notch impact value at room temperature after it has been quenched, reheated to 500–600° C. (reheating after quenching is called "drawing;" see definition of "Annealing" in Appendix of Vol. I) and cooled slowly. The tensile ductility is unaffected by temperature and rapidly cooling from the drawing temperature prevents temper brittleness. It is only the notch impact value that is affected and only at room temperature, for at 100° C. the temper-brittle steel has as high a notch impact value as the steel that is free from temper brittleness.

Cracks

Cracks represent the failure under stress of a material when it is behaving in a brittle fashion. Having discussed the conditions under which steel and weld metal may exhibit brittle behavior, we now consider the types of cracks that may occur. It will be well to classify cracks according as they occur in base metal or in weld metal and also as they occur during cooling or after the part has been placed in service.

Starting with hot cracks, we find these in weld metal that has been deposited incorrectly so as to force the last metal to solidify to undergo excessive deformation or—what amounts to the same thing—excessive tensile stress. Besides being deposited incorrectly the weld metal has a composition favorable to the retention of small amounts of liquid as films throughout the metal long after the majority of the metal has solidified.

Hot cracks are not confined to weld metal but may be observed in base metal as well. A good example is the intergranular crack found at the edge of welds in aircraft sheet and tubing containing approximately 0.35% C, 1.0% Cr and 0.20% Mo. The crack is found in the base metal at its juncture with the weld bead, which is generally low-carbon steel. The crack is covered with oxide, showing that air entered the crack while the metal was at least red hot. It is easy to deduce that the crack occurred because the hot base metal was brittle and could not deform in conformity with the distortions that the remainder of the joint was undergoing. But the question has never been answered whether liquid films appeared in the grain boundaries and so caused brittleness.

It is important to observe that it is the inability to deform without cracking, rather than the strength of the metal at the temperature of cracking, that governs the appearance of the crack. If the metal is able to deform, it makes little difference whether its strength is 100 or 10,000 lb./in.^{2}, because in welding a given type of joint, such as a butt weld in sheet, the shrinkage and distortion is very largely independent of the strength of the metal, but is related closely to the heat input, that is, the size of flame and speed of welding. The cracks are favored by welding processes involving large heat inputs. The cracks may be prevented, therefore, by reducing the heat input, which is accomplished in oxyacetylene welding by adopting "carburizing flux" technique. A reducing flame is used to raise the carbon content of the scarves, thus lowering the temperature at which they melt and decreasing the heat input.

There is no further tendency, ordinarily, for cracks to form in the welded joint during cooling until the temperature has fallen below about 300° C., barring excessively rigid conditions, sharp notches and tri-axial tensile shrinkage stress. Cracks due to hardening form between about 300° C. and room temperature, provided: (1) the steel contains more than 0.2% C; (2) the cooling rate at the edge of the weld is sufficiently high that the austenite has not been given time to transform fully to pearlite (or troostite as pearlite, in which the plates of ferrite and cementite are very close together, sometimes is called); (3) the distortion caused by welding is forced to occur in the hard zone, which is not capable of deforming.

Turning to the consideration of cracks that may form after the welded joint has been placed in service, we observe that the most dangerous are those which require only slight deformation to start them. Rarely are welded parts required or designed to undergo severe deformation in service. Rather, they are expected to resist occasional overload without sudden, brittle failure. Our discussion

of brittleness earlier in this lecture suggests that brittleness in service is likely to be exhibited under three conditions: (1) hard zones, (2) bi-axial and tri-axial stress, (3) notches.

The danger associated with hard zones was illustrated in Fig. 19. When the hard zone snaps, the crack tends to spread rapidly into the weld metal, and particularly, as experience shows, into the base metal. The base metal must be sufficiently tough to prevent the spread of the crack—a severe requirement. It is usually safer and preferable to remove hard zones by stress-relief heat treatment or to prevent their occurrence by suitable choice of low-carbon steel as base metal or by preheating.

Cracks caused by bi-axial or tri-axial stress are to be guarded against in thick material, for it rarely happens that the stress in the direction of the thickness is high in thin material. Since the stress in the direction of the thickness, Fig. 22 (*a*), must be zero at both surfaces of the plate it can become high near the center only if the plate is thick. An example of the conditions under which tri-axial stress may occur is shown in Fig. 22 (*b*). The heavy-walled pipe connects the two rigid receivers *A* and *B*. We will see later that tensile shrinkage stresses due to a weld may act in two directions, while the tangential stress due to internal pressure acts in the third direction. Since the pipe and weld are subjected to tri-axial tensile stress, which will favor a brittle crack under sudden overload, stress-relief heat treatment always is applied to these types of joints. In any event, weld metal is no more sensitive to brittle cracks under tri-axial stress than the wrought pipe itself.

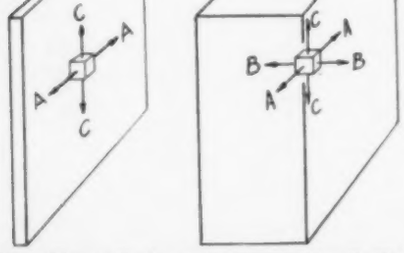


Fig. 22 (*a*)—Stress Perpendicular to the Surface Can Be High Ordinarily Only in Thick Plates

In the thin plate at the left there can be practically no stress perpendicular to the surface. In the center of the thick plate at the right it is possible for high tensile stresses to act in three directions at right angles. The tiny cubes represent elementary particles in the plate. The arrows represent the direction of stress

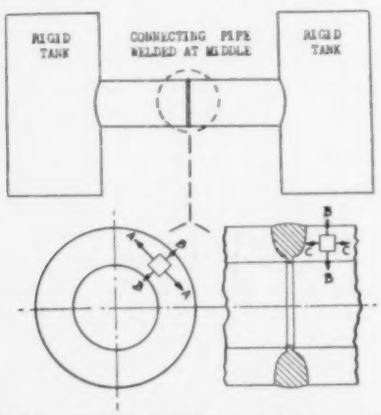


Fig. 22 (*b*)—Shrinkage Stresses in a Weld in a Pipe Connecting Two Rigid Tanks

A = Stress due to internal pressure in the pipe
B = Shrinkage stress due to welding
C = Shrinkage stress due to restraint during welding

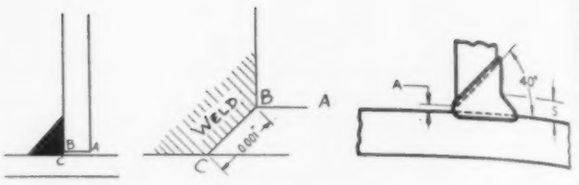


Fig. 23

(*a*) The drawing at the center shows the character of the notch at *BC* (the root of the fillet weld) at high magnification
(*b*) 40° single bevel tee joint avoiding excessive stress concentration at the root (United States Steel)
S = Size of fillet
A = Root opening

The brittleness likely to be exhibited at notches is specially important for welding, Fig. 23 (*a*). The notch is bounded by the edges of the plates *AB* and *CD*, and by the root of the weld, represented for simplicity as a straight line, 0.001 in. long. When the leg of the *T* is bent in the direction shown by the arrow the face of the fillet is compressed but the root is placed under tensile stress. It is easy to see that a motion of the leg of the *T* sufficient to move the end of the plate *AB* 0.001 in. will force the root of the fillet to yield 0.001 in., that is, 100% elongation. Is it surprising if the metal fails? To avoid the notch the type of joint should be changed to that shown in Fig. 23 (*b*).

Summary

The types of brittleness have been described followed by a discussion of the cracks which may be caused by the brittleness. By way of summary, we shall outline briefly the methods of avoiding cracks. If the crack occurs during welding, the first step toward curing the condition is to reduce the restraint at the joint, by loosening jig bolts, for instance. A hot crack is given away by its blued or scaled appearance; a cold crack has a metallic surface.

A change in welding technique also may reduce the rigidity indirectly by reducing the distortion. Over-all distortion generally is diminished by wandering sequence, which reduces the amount of hot, plastic metal which shrinkage can deform. Distortion is generally reduced by decreasing the rate of heat input. Rate of heat input may be decreased by increasing the welding speed without changing the size of flame or current. However, decrease in rate of heat input favors cold cracks, to cure which it is often desirable to increase the heat input by using large electrodes and high currents, at correspondingly slow speeds. Preheating to 200 or 300° C. is a positive cure for cracks due to hardening. I the crack is due to a root notch that is being opened into a crack by the distortion accompanying succeeding layers of weld metals, peening should be tried to reverse the distortion. Finally, if the cracking is a chronic disease that affects every new type of joint attempted in the material and that can not be cured with certainty by any practicable changes in technique, it is time to consider a new material having more favorable characteristics.

Questions

1. In what ways may welds exhibit brittleness?
2. Name five ways of preventing slip. Why is prevention of slip equivalent to creation of brittleness?
3. What is a crack?
4. A crack is found in a welded joint. How would you diagnose the cause of the crack from its appearance?
5. What precautions should be taken to prevent hot cracks? cold cracks?

Welding of Passenger Cars*

By A. M. Unger†

THE girder type of passenger car is built with flat sides. The smooth sides with no projections give a very pleasing appearance and are easy to clean.

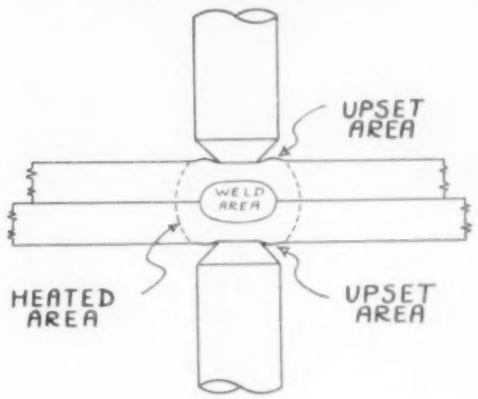
Many problems had to be solved to produce the smooth side. In the old days of riveted cars, buckles in the side sheets were not so objectionable because the rows of rivet heads drew the attention of the eye. These evenly spaced rivets in straight rows gave an explanation for dips and bulges in the side sheets. When spot welds replaced the rivets in the car side, there were no projecting rivet heads to hide the buckles. It therefore became necessary to make a better side with spot welding than had been made with riveting.

The first experimental panels that were spot welded showed that considerable trouble with buckling would be experienced. Spot welding of a car side consists of vertical rows of welds on the side posts and horizontal rows of welds on longitudinal framing members at the top and bottom of the side and at the top and bottom of the windows. This means that the car side is divided into panels having spot welds completely around their perimeter. The panels are formed above and below the windows and in between windows.

SHRINKAGE OF SPOT WELDS

Each spot weld shrinks a certain amount. The reason for this shrinkage can be shown by considering what happens when a spot weld is made. Figure 1 shows a cross section through a spot weld. The volume of metal included between the two welding electrodes is heated to a high temperature, in some cases even to a melting temperature. Metal expands with heat; therefore the heated metal between the spot-welding electrodes tends to increase in volume. It is restricted in its expansion by the cold metal surrounding the heated area. The expansion force is very great and results in upsetting of the metal around the outer edge of the weld. This is illustrated in Fig. 1. This force is so great that even with a flat electrode against one side, in many cases an upset ring will be found. On cooling of the weld, the upset metal cannot return to its original position and the dimension of the weld reduces slightly. While this value may be small for each individual weld, the total for a series of welds can easily be measured. An experiment was conducted by making a row of spot welds on

Fig. 1—Illustrating Upsetting Around a Spot Weld Due to Expansion of Heated Metal



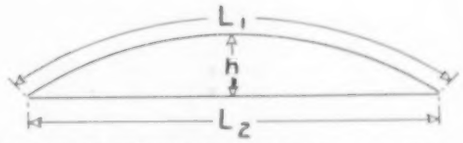


Fig. 2—Height of Buckle Produced by Change in Dimension of Framing

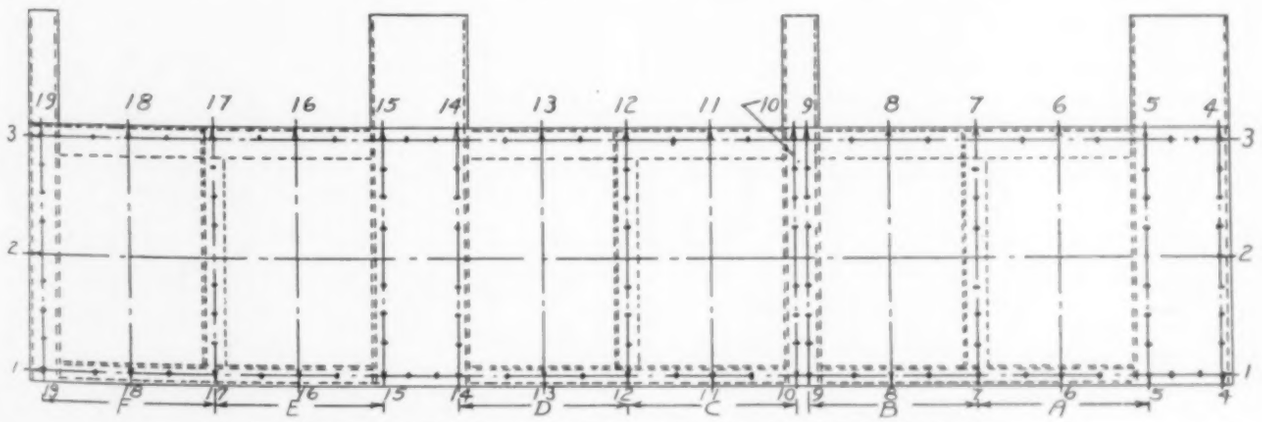


Fig. 3—Sketch Showing Measurement Taken on Car Side. Sample Welded for Buckles

* Presented at the Annual Meeting, A. W. S., Cleveland, Ohio, October 21 to 25, 1940.

† Development Engineer, Pullman-Standard Car Mfg. Co., Chicago, Ill.

Table 1—Change in Length of Panel While Welding and Peening

(Measurements Taken as Shown on Fig. 3)

Location of Measurement	Original Sheet	After Vertical Spots	Check	64th Change from Original	After Horizontal Spots	64th Change from Vertical	64th Change from Original	After Peening	64th Change after Welding	64th Change from Original
No. 1-1	120 20/64	120 16/64		−4	120 15/64	−1	−5	120 15/64	0	−5
2-2		120 19/64			120 17/64	−2		120 24/64	+7	
3-3	120 22/64	120 20/64		−2	120 18/64	−2	−4	120 22/64	+4	0
4-4	23 33/64	23 34/64	23 34/64	+1	23 33/64	−1	0	23 34/64	+1	+1
5-5			23 34/64	+1	23 33/64	−1	0	23 34/64	+1	+1
6-6			23 34/64		23 34/64	0		23 35/64	+1	
7-7			23 34/64		23 34/64	0		23 35/64	+1	
8-8			23 35/64		23 34/64	−1		23 35/64	+1	
9-9	23 35/64	23 34/64	23 34/64	−1	23 34/64	−1	−2	23 35/64	+1	0
10-10			23 34/64	−1	23 34/64	0	−1	23 35/64	+1	
11-11			23 35/64		23 34/64	−1		23 35/64	+1	
12-12			23 35/64		23 34/64	−1		23 35/64	+1	
13-13			23 36/64		23 35/64	−1		23 35/64	0	
14-14	23 35/64	23 34/64	23 34/64	−1	23 34/64	0	−1	23 34/64	0	−1
15-15			23 34/64	−1	23 33/64	−1	−2	23 34/64	+1	−1
16-16			23 36/64		23 33/64	−3		23 33/64	0	
17-17			23 34/64		23 33/64	−1		23 33/64	0	
18-18			23 35/64		23 33/64	−2		23 33/64	0	
19-19	23 33/64	23 32/64	23 32/64	−1	23 32/64	0	−1	23 34/64	+2	+1

two pieces of 16-gage steel, $1^1/_2$ inches in width. The length of the specimen was 24 inches. It was found that there was a reduction in length of $^1/_{64}$ of an inch after being welded together.

As a result of this shrinkage, a panel that is surrounded by a row of spot welds has its outer perimeter shortened. The natural result of this is to throw a bulge in the panel.

BUCKLING OF PANELS

An idea of the small amount of shrinkage required to produce a rather large buckle is given by some calculation. Assume the buckle to be the arc of a circle, and the amount of buckle to be the height (h) of the arc from the chord (Fig. 2). L_1 is the original width of the panel; L_2 is the width after spot welding. $L_1 - L_2$ is the amount of shortening that has occurred in the framework.

Using standard commensuration formulas for circles, it is found that, for a panel 17 inches in width, only a reduction in length of 0.01 inch is necessary to produce a $^1/_4$-inch buckle.

The $^1/_{64}$ of an inch shrinkage obtained in the 24-inch strip would be proportionally a shrinkage of 0.011 inch in a 17-inch length.

To actually check this shrinkage on a panel, a section of a car side was spot welded. The section built is shown in Fig. 3. It consists of a 10-foot length below the window openings. All material was $^3/_{32}$ inch thick, i.e., posts, stiffeners, sills and outside sheet. Spot welds $^5/_{16}$ of an inch in diameter, spaced one inch apart, were used. There were four vertical posts. The panel between the posts was divided by a stiffener. This formed six panels, which were called A to F, inclusive. Measurements to determine the over-all shrinkage were taken at points marked 1-1 to 19-19, inclusive, on Fig. 3. After these measurements were made, the spot welds were peened and the over-all length again measured. The results of these measurements show an over-all shrinkage due to the spot welding, and an over-all expansion due to the peening. The measurements taken are given in Table 1.

Buckles in the panels were measured at five different times. They were as follows:

(a) After welding vertical rows of spot welds.
(b) After welding horizontal rows of spot welds.
(c) After peening adjacent panel to the right.
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The buckles were measured with the straight edge in a horizontal position at four different points on the vertical dimension of the panel. These measurements are plotted in Fig. 4.

The curves give a good idea of the variation in buckles due to the welding and peening. In some panels a decided improvement can be seen due to the peening. Even peening of adjacent panels had considerable effect. Panel C shows a decided improvement due to the peening. Too much peening also created buckles.

Peening to eliminate buckles was actually tried in production. It soon became apparent that, while the buckles could be eliminated, the best results would be obtained if the buckles were prevented from forming in the first place.

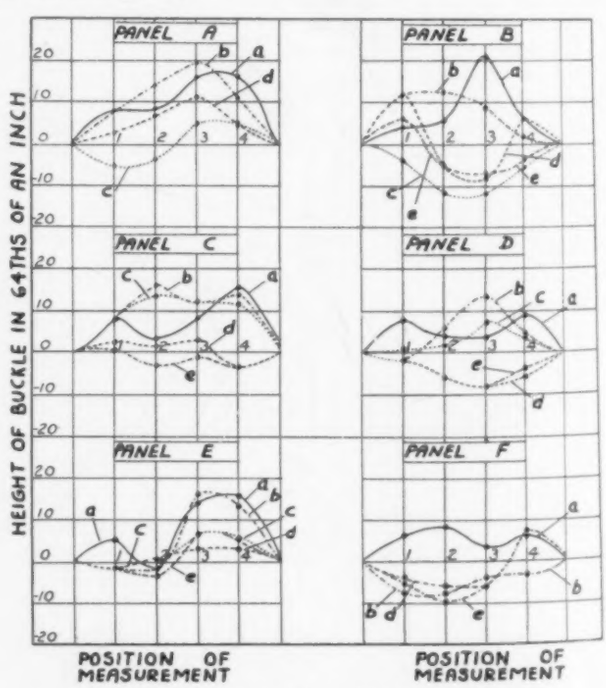

Fig. 4—Buckle Variation Due to Welding and Peening

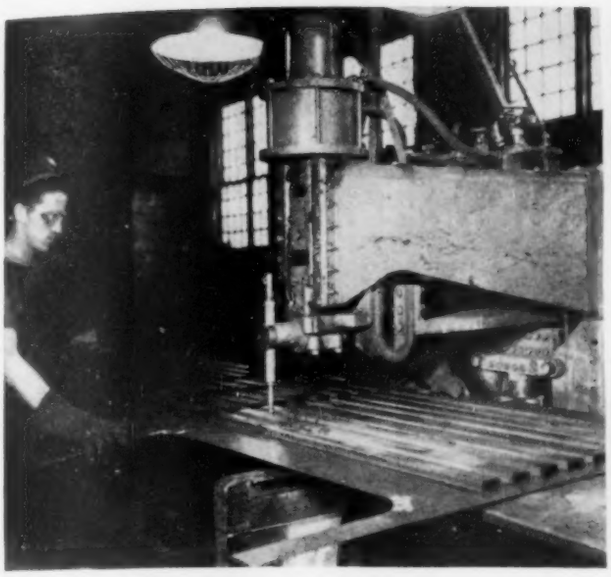

Fig. 5—Stiffener to Eliminate Warpage Due to Shrinkage of Spot Welds in Side Sheets

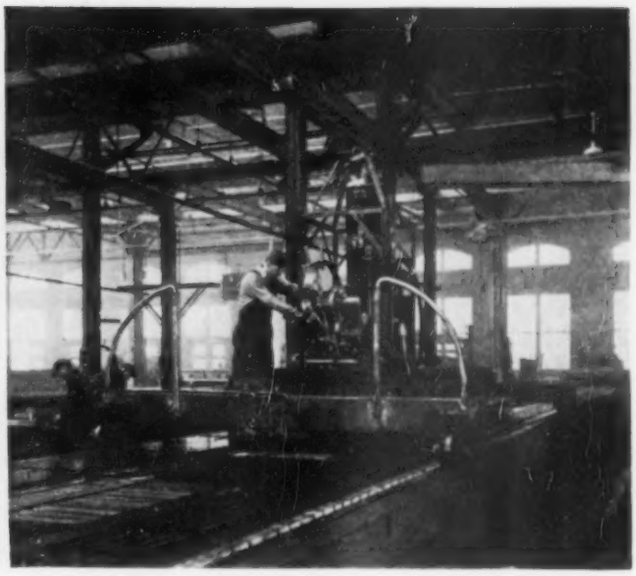

Fig. 6—Joining Side Sheets Together by Union Melt Process

ELIMINATION OF BUCKLES

In the study that was made of buckles, it was found that, besides the buckles formed by the shrinkage of the spot welds; there were others caused by shrinkage of arc welds on the framing. To prevent this from having any effect on the outside sheet, it was decided to build the frame separately and to have all the arc welding completed before the sheet was attached to the framing so that all the shrinkage would have taken place previously to being attached to the sheet.

To prevent the shrinkage of the spot welds that join the side sheet to the framing from causing buckles, it was decided to stiffen the side sheet by the addition of a very light-gage, corrugated stiffener spot welded to the outside sheet. This stiffener would have strength enough to resist the stresses set up in the sheets by the shrinkage of the spot welds. A stiffener of this type is shown in Fig. 5.

The stiffener worked out very well in production, eliminating any straightening, and produced the smooth side desired.

PROCEDURE FOR BUILDING A CAR SIDE

The side sheet of a car is divided into an average of 16 sections. These sections are joined by a horizontal butt weld into 8 vertical sections. These vertical sections are joined together by 7 vertical butt welds to form the complete side.

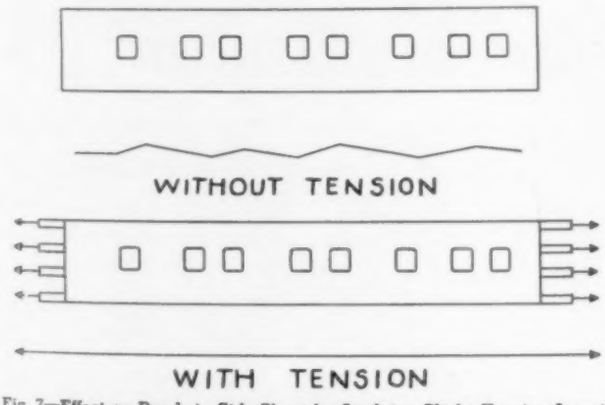

Fig. 7—Effect on Bends in Side Sheet by Applying Slight Tension Longitudinally

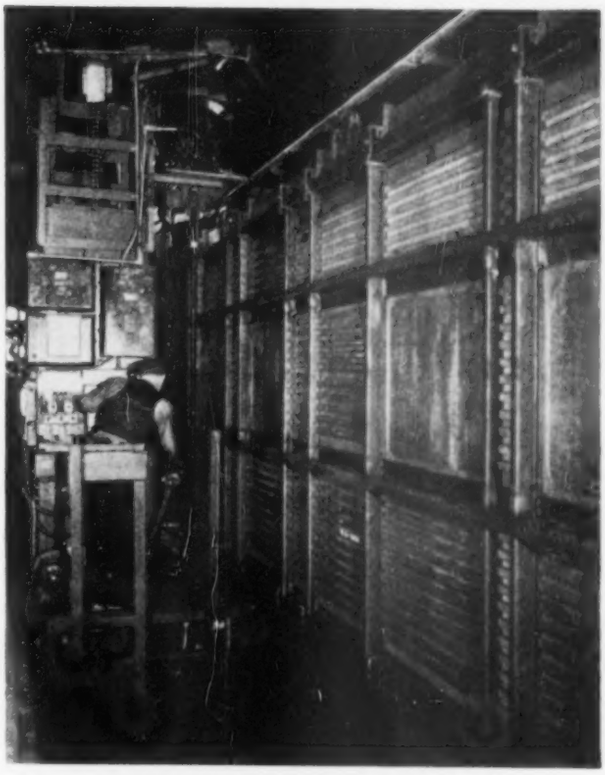

Fig. 8—Spot Welding Side Frame to Side Sheets

Before welding the sections together, corrugated side sheet stiffeners are spot welded to each section as shown in Fig. 5. They are gaged so as to allow space for the framing members in the proper locations.

The sheets are joined together by the Union Melt process (Fig. 6). After grinding the weld bead flush on the outside surface, the sheet is clamped against the spot-welding jig. The side that is to be the outside of the car is placed against the jig.

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The curves give a good idea of the variation in buckles due to the welding and peening. In some panels a decided improvement can be seen due to the peening. Even peening of adjacent panels had considerable effect. Panel C shows a decided improvement due to the peening. Too much peening also created buckles.

Peening to eliminate buckles was actually tried in production. It soon became apparent that, while the buckles could be eliminated, the best results would be obtained if the buckles were prevented from forming in the first place.

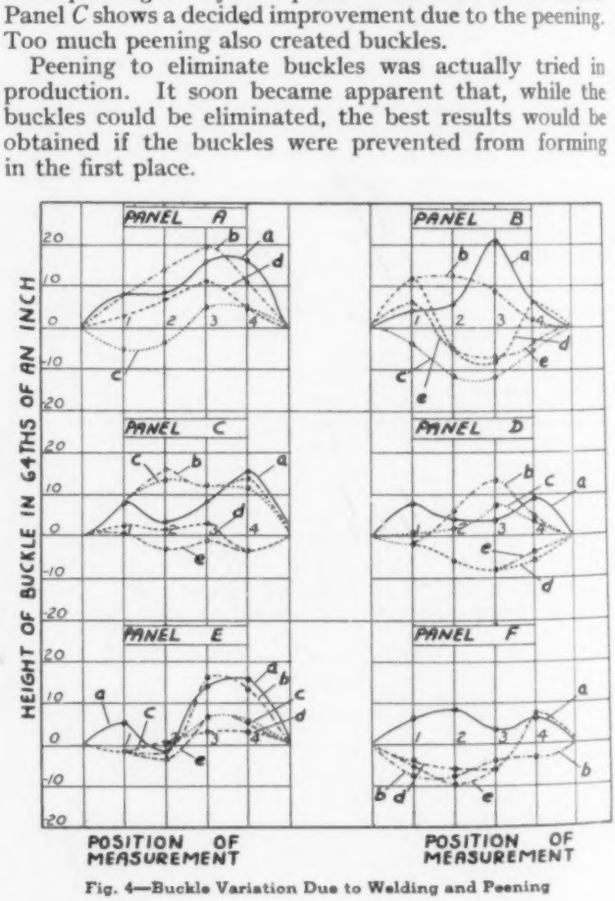

Fig. 4—Buckle Variation Due to Welding and Peening

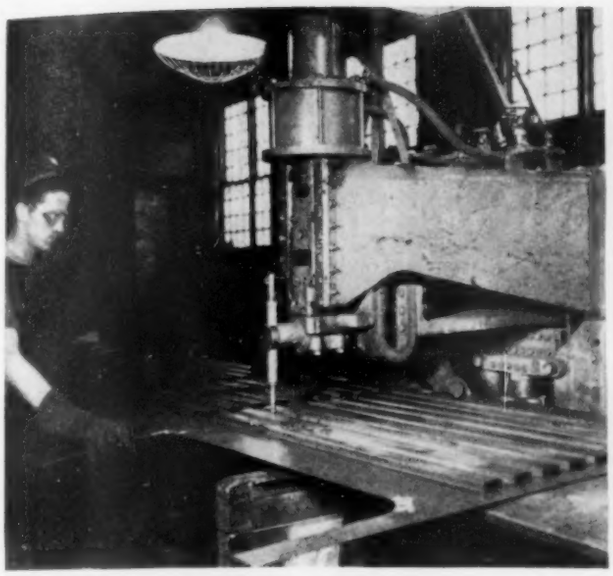

Fig. 5—Stiffener to Eliminate Warpage Due to Shrinkage of Spot Welds in Side Sheets

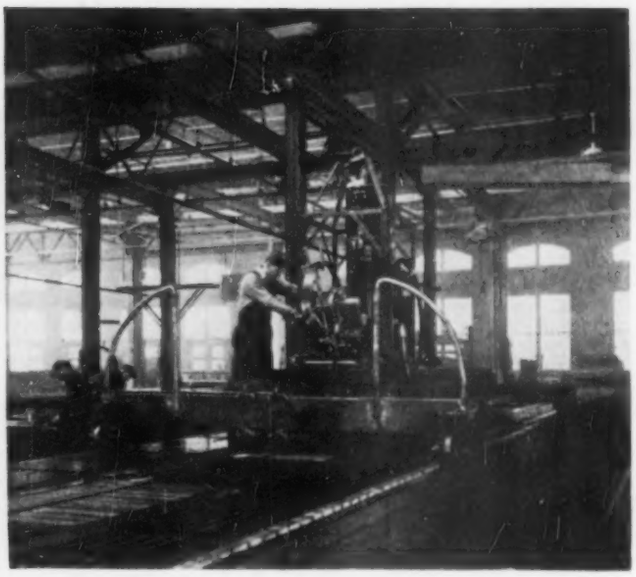

Fig. 6—Joining Side Sheets Together by Union Melt Process

ELIMINATION OF BUCKLES

In the study that was made of buckles, it was found that, besides the buckles formed by the shrinkage of the spot welds, there were others caused by shrinkage of arc welds on the framing. To prevent this from having any effect on the outside sheet, it was decided to build the frame separately and to have all the arc welding completed before the sheet was attached to the framing so that all the shrinkage would have taken place previously to being attached to the sheet.

To prevent the shrinkage of the spot welds that join the side sheet to the framing from causing buckles, it was decided to stiffen the side sheet by the addition of a very light-gage, corrugated stiffener spot welded to the outside sheet. This stiffener would have strength enough to resist the stresses set up in the sheets by the shrinkage of the spot welds. A stiffener of this type is shown in Fig. 5.

The stiffener worked out very well in production, eliminating any straightening, and produced the smooth side desired.

PROCEDURE FOR BUILDING A CAR SIDE

The side sheet of a car is divided into an average of 16 sections. These sections are joined by a horizontal butt weld into 8 vertical sections. These vertical sections are joined together by 7 vertical butt welds to form the complete side.

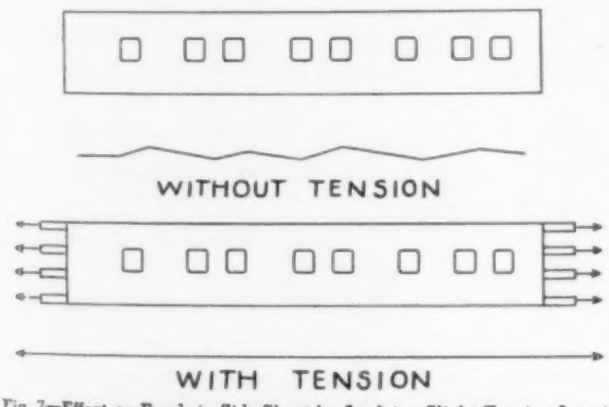

Fig. 7—Effect on Bends in Side Sheet by Applying Slight Tension Longitudinally

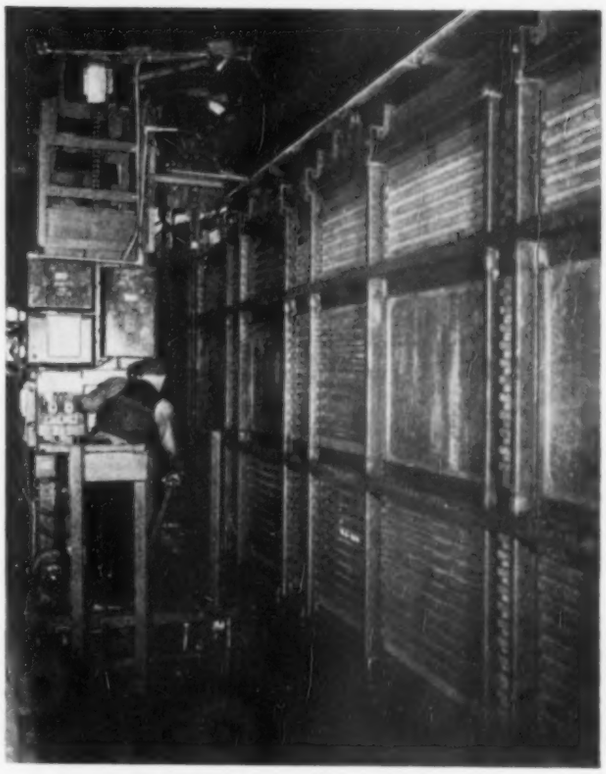

Fig. 8—Spot Welding Side Frame to Side Sheets

Before welding the sections together, corrugated side sheet stiffeners are spot welded to each section as shown in Fig. 5. They are gaged so as to allow space for the framing members in the proper locations.

The sheets are joined together by the Union Melt process (Fig. 6). After grinding the weld bead flush on the outside surface, the sheet is clamped against the spot-welding jig. The side that is to be the outside of the car is placed against the jig.

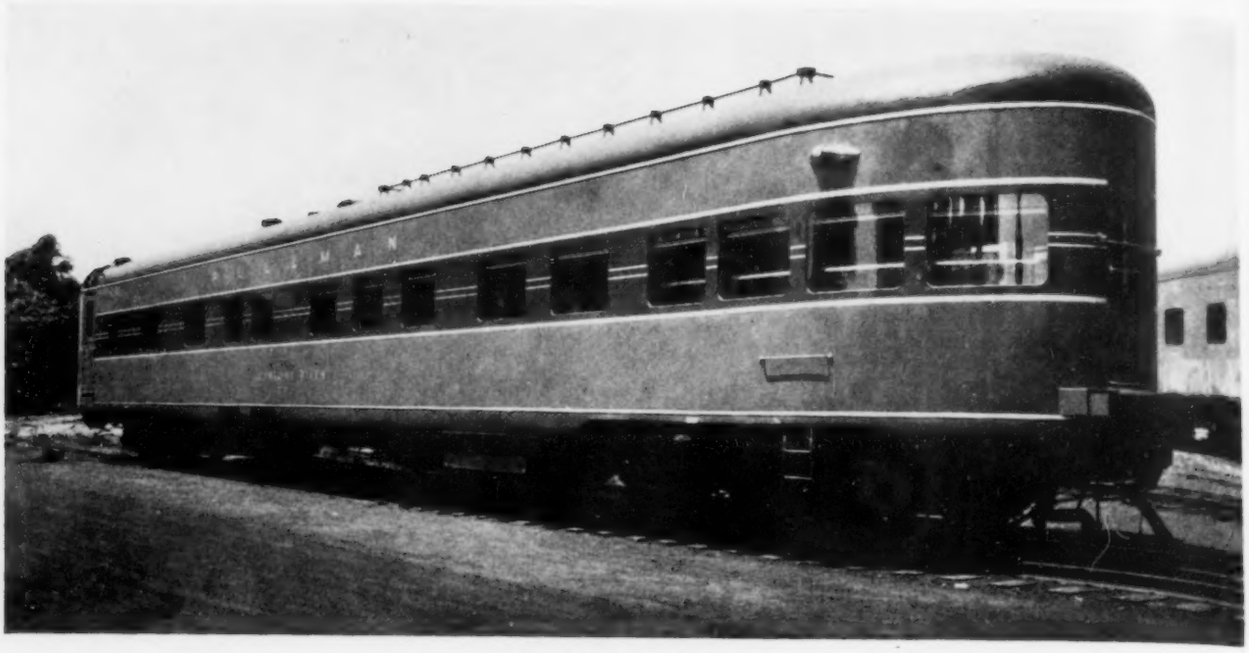

Fig. 9—The Completed Car

The spot-welding jig consists of a supporting framework holding in a vertical position a copper plate 8 feet 10 inches high and 85 feet long. As the welds are made in series, the copper plate serves as a current conducting back-up to carry the current from one electrode to the other after it has passed through the side being welded.

A copper plate is used instead of individual back-up bars so that no jig change will be required from one plan of car to another. No matter where the framing members are located, they are always backed up by the copper plate.

All looseness or kinks that may be in the sheet before spot welding to the frame are eliminated before spot welding to the side framing, as illustrated in Fig. 7.

The side frame is fitted and arc welded in a separate jig into one complete unit. As mentioned before, all the arc welding is completed in this position so that the only welding that remains to be done is the spot welding to the side sheet. After the arc welding is completed, the welds on the surface that goes against the side sheet are ground flush. The frame is checked for straightness, straightened and then clamped against the side sheet on the spot-welding jig.

The spot welding of the frame to the side sheet is done with the outside of the car against the copper plate on the side jig. This eliminates the indentations of the electrodes on the outside sheet.

A spray of water surrounds each electrode to prevent the heat of the welding from expanding the framing members. If the frame were allowed to expand, it would be spot welded in this condition and would result in buckling of the side sheets.

The spot-welding machine used has been described in a previous article, published in the June 1938 issue of THE WELDING JOURNAL.

A completed car is shown in Fig. 9. Note the smooth, flush sides.

FUTURE MEETINGS AND CONFERENCES

American Chemical Society. April 7–11, 1941, St. Louis, Mo.

American Institute of Chemical Engineers. Semi-annual meeting, May 19–21, 1941, Chicago, Ill.

American Society for Testing Materials. Annual Meeting, June 23 to 27, 1941, Palmer House, Chicago.

American Society of Civil Engineers. Spring meeting, April 23–25, 1941, Baltimore, Md.

American Welding Society. Annual Meeting, October 20 to 24, 1941, Bellevue-Stratford Hotel, Philadelphia.

Association of Iron and Steel Engineers. Annual Spring Conference, Monday, April 28, 1941, Ohio Hotel, Youngstown, Ohio.

Annual Convention, Sept. 23, 24 and 25, 1941, Cleveland, Ohio.

Electrochemical Society. Spring meeting, April 16–19, 1941, Cleveland, Ohio.

Michigan State College Welding Conference, April 25 and 26, 1941, E. Lansing, Mich.

Midwest Power Conference. April 9–10, 1941, Chicago, Ill.

National Electrical Manufacturers Association. May 11–15, 1941, Hot Springs, Va.

National Association of Purchasing Agents, May 26–29, Stevens Hotel, Chicago, Ill.

New England Welding Conference, April 25 and 26, 1941, Massachusetts Institute of Technology.

Western Metal Congress and Exposition. Los Angeles, Calif., May 19 to 23, 1941.

Condenser Discharge Welds Tube to Disk

By H. S. Card*

IN THE fabrication of a part of a motor support which requires the assembly of a tube to a flat washer, a manufacturer of welded steel tubing makes use of the Vanco welding process. This process is essentially as follows:

Condensers of suitable capacity are charged with current from a standard power line. The current is stepped up to approximately 4000 volts with an iron core transformer that is contained in the charging unit. A vacuum tube acts as a check to produce direct current and a timer controls the charge in the condenser. The parts to be welded are clamped in suitable fixtures, one of which is connected to the condenser and held in a movable slide against pressure until the condensers are

charged. Upon releasing a trigger, one piece moves toward the other rapidly. When it reaches a distance of about $^1/_{16}$ inch, an arc breaks across the gap, producing a molten condition on both surfaces, and the two surfaces are brought together while still molten. The penetration of heat is very shallow and the weld is made with a small amount of flash which is negligible for all practical purposes.

In the illustration there is shown a piece of welded S. A. E. 1010 steel tubing $^5/_8$ inch O.D. by 0.084 inch wall welded to a flat steel washer $2^1/_2$ inches in diameter, 0.104 inch thick. The hole in the washer is in line with the interior tube wall, permitting a $^3/_{16}$ inch rod to slide through the assembly. The welding cycle in this case is completely automatic, with maximum capacity of 1800 welds per hour. Over a long period, production has averaged 1200 pieces per hour including stoppages for all reasons.

* Director, Product Development, Formed Steel Tube Institute, New York.

THESE JOINTS WILL BE PERMANENTLY LEAK-TIGHT

Brazing copper connections to copper header of booster unit for return line of a 5-ton refrigerating system.

They're being brazed with SIL-FOS

This is but one example showing why Industry in general is making widespread use of Sil-Fos Brazing Alloy. The reasons for this general use all boil down to SPEED—RELIABILITY—ECONOMY.

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RELIABILITY Because of its extreme fluidity, Sil-Fos gets down **into** the joint and actually alloys with metals to make gas-tight joints. The silver in this alloy assures high strength and ductility to withstand severe vibration, shocks, and wide temperature changes.

ECONOMY Low working temperature, fast penetration, the small amount of alloy needed and the reduction or elimination of rejects—all combine to save labor, heat and materials. Reports from users after changing to Sil-Fos show **reductions in cost per joint often as high as 50%.**

TRY SIL-FOS Pick out a non-ferrous metal job on which you would like to improve joint quality, speed up production or cut costs and try Sil-Fos on it. We'll be glad to help you make any test—or to demonstrate Sil-Fos. Bulletin WJ-5 gives Sil-Fos details. Write for a copy today.

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Welding Society

ACTIVITIES — Related Events

NOMINEES FOR DISTRICT VICE-PRESIDENT

New York-New England: E. R. Fish, Hartford Steam Boiler Insp. & Ins. Co., Hartford, Conn.

Middle Eastern: A. G. Bissell, Bureau of Ships, Navy Department, Washington, D. C.

Middle Western: L. S. McPhee, Whiting Corporation, Harvey, Ill.

Southern: J. A. Hall, Kansas City Structural Steel Co., Kansas City, Kan.

Pacific Coast: N. F. Ward, University of California, Berkeley, Calif.

Article V, Section 6, By-Laws: ". . . The nominations made by the Districts shall be published in the April issue of THE WELDING JOURNAL of the AMERICAN WELDING SOCIETY."

"Independent nominations may be made by a petition of twenty-five (25) or more members sent to the National Secretary not later than May 15th; such petitions for the nomination of District Vice-Presidents shall be signed only by members within the district concerned.

"Only District members shall be eligible to vote for District Vice-Presidents."

THE PRESIDENT'S LETTER

Statements are frequently heard that the progress of welding is held back because our colleges and universities have no adequate courses of instruction on the subject. On the other hand, some engineering schools have experimented with welding courses and are still uncertain as to what types of courses, if any, are required.

The duties of the welding engineer are varied. In some organizations he may be concerned with arc welding, gas cutting, or with gas welding, and in others with some form of resistance welding. In some cases he may be used on work involving all types of welding. He may be associated with practical fabrication work or with research activities or he may be used as a design engineer on welded structures. His product may be of heavy section or of extremely light section. The materials used may be low carbon steel, a high alloy steel or the various non-ferrous metals. As a practical welding engineer his advice will be sought in the design of welded structures, the selection of metals and in the method of inspection and tests. In some plants he may be concerned with the design and construction of special welding equipment.

A knowledge of the welding processes is only a part of this training. He must have acquired a knowledge of the metallurgy, testing engineering, civil and mechanical engineering for the analysis of stresses and the design of structures and of electrical engineering for an understanding of the process and the equipment used. His knowledge of materials should be rather intimate as he is concerned with their limitations as well as their properties and characteristics. Certainly a highly interesting course of instruction could be laid out for the training of welding engineers.

What is the demand for engineers of such training? The welding industry is rapidly expanding and under current conditions many welding engineers could be placed. But what is the ordinary annual demand for men of such training? If four years are required for training, the demands need to be predicted four years in advance and the prediction must consider the probable growth of welding.

If there is a danger that our engineering schools are not anticipating the requirements of industry, the problem should now receive far more careful consideration.

WESTERN METAL CONGRESS

Four welding sessions have been arranged by the Los Angeles section of the AMERICAN WELDING SOCIETY as features of the Western Metal Congress, May 19th to 23rd in the Biltmore Hotel and Pan-Pacific Auditorium, Los Angeles.

J. C. Gowing, vice-chairman of the Los Angeles section, who is program chairman, announced these welding sessions will be held in the hotel on the mornings of May 19th, 20th, 21st and 22nd. He is assisted in planning the program by E. O. Williams, secretary of the Los Angeles section.

The program for the welding sessions tentatively stands as follows:

May 19th: Dr. G. V. Slottman, Air Reduction Sales Co., New York, "Flame Machining;" H. C. Bell, The Linde Air Products Co., Los Angeles, "Union-Melt Process in Ship Building;" L. W. Delhi, Western Pipe and Steel Co., San Francisco and Pacific Coast District Vice-President of the AMERICAN WELDING SOCIETY, "All Welded Ships."

May 20th: F. C. Fantz, Midwest Piping and Engineering Co., St. Louis, "Welded Pressure, High-Temperature Steam Piping;" F. A. Hurcomb, Taylor-Winfield Co., Warren, Ohio, "Resistance Welding;" Dr. V. N. Krivobok, Lockheed Aircraft Corp., Burbank, Calif., "Welding of Stainless Steel in the Aviation Industry."

May 21st: T. B. Jefferson, editor, *Welding Engineer*, Chicago, "Training of Welding Operators;" Turner Smith, General Petroleum Corp., Los Angeles, "Codes and Specifications."

May 22nd: Prof. N. F. Ward, University of California, Berkeley, "Welding Construction and Design of Landing Gears;" Charles J. Gallant, North American Aviation Co., Los Angeles, "Arc Welding of Chrome-Moly Tubing and Plates in Aircraft Industries;" Francis Stevenson, Vega Airplane Co., "41-30X—Practical Application in Tubular Structures of Aircraft."

Speakers for "Foundry Day," May 23rd, programmed by American Foundrymen's Association, include Dr. C. H. Lorig, Battelle Memorial Institute, Columbus, subject unannounced; E. K. Smith, Electro Metallurgical Corp., Detroit, "Heat and Wear Resistant Cast Iron;" V. A. Crosby, Climax Molybdenum Co., Detroit, "Plain and Alloyed Cast Iron." Several other foundry speakers will be announced soon.

Keyed to exigencies of national defense, the technical program of the Metal Congress has been declared the finest from a standpoint of new aids to production yet scheduled for the Pacific Coast.

Officers and directors of the American Society for Metals and many other recognized authorities are programmed for the Congress' five days of technical sessions, according to Dr. D. S. Clark, associate professor of mechanical engineering, California Institute of Technology, Pasadena, who is Congress program chairman.

As there are twice as many men engaged in metal work as there were in 1938 when the meet last was held in Los Angeles, William H. Eisenman, secretary, predicted 50,000 will attend the Western Metal Exposition to be held on the same dates in Pan-Pacific Auditorium. In 1938, exposition attendance totaled 35,000.

Concerning the physical aspect of exposition, Mr. Eisenman said it will occupy more space and will have more exhibitors than ever in its history in the west.

EXECUTIVE COMMITTEE HOLDS INTERESTING MEETING

The Executive Committee of the AMERICAN WELDING SOCIETY held a meeting on February 13th. There were present:

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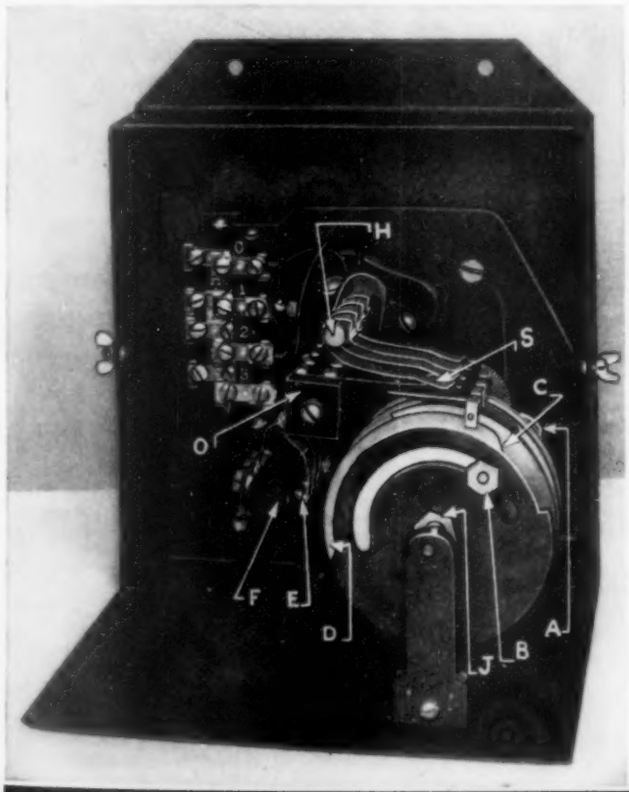

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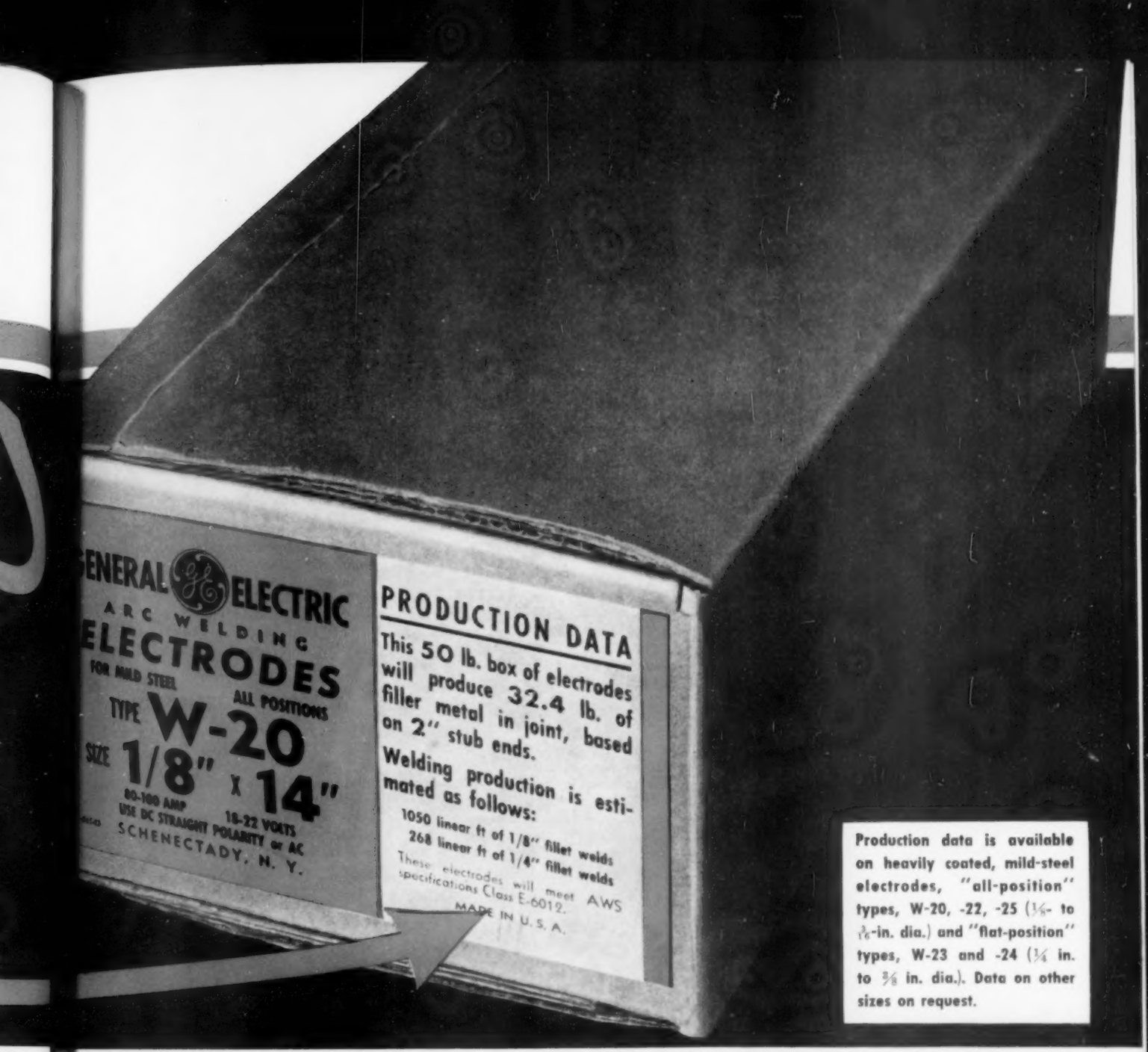
Welding supervisors and foremen can now assure their shops a constantly fresh, adequate supply of electrodes. Knowing the estimated welding footage possible from every type and size of rod they use, or plan to use, purchasing agents can now co-ordinate deliveries with known future requirements.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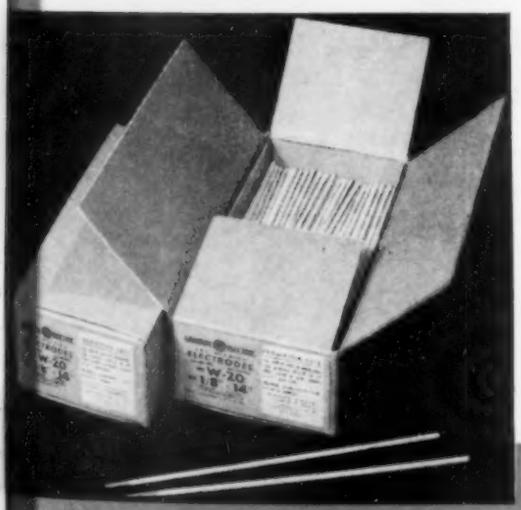

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GENERAL ELECTRIC

673-20-8748

G. F. Jenks, *President*, presiding; A. J. Bissell, H. C. Boardman, R. W. Clark, E. V. David, E. R. Fish, O. B. J. Fraser, H. O. Hill, D. S. Jacobus, Albert S. Low, L. S. Moisseiff, A. C. Weigel, W. Spraragen and M. M. Kelly, *Secretary*.

Financial Report

Treasurer Moisseiff reported that the finances were in excellent shape and that the budget had been bettered both on the income side by additional revenue and on the expenditure side by savings effected.

1941 Annual Meeting Budget

The Annual Meeting budget for 1941 totaling $3800 for direct expenditures was approved.

McCune Memorial

It was the consensus of opinion that a memorial in a form to be determined should be established to perpetuate the name of C. A. McCune in recognition of his leadership and service to the Society and to the welding industry; that it should be self-supporting and the membership given an opportunity to pledge its support; that a trust fund should be set up through contributions from the membership, and because of Mr. McCune's many friends, acquired over the years in building up the Society, it was felt there should be no difficulty in raising a sum sufficient to make provision for the medal over a period of fifteen years or more.

R. W. M. A. Prize Contest

It was agreed that the A. W. S. accept sponsorship for the judging and awarding of Resistance Welder Manufacturers' Association cash prizes totaling seven hundred dollars for papers on Resistance Welding. The rules are published in the Year Book. The contest opened September 1, 1940, and closes midnight August 31, 1941.

Aircraft Steel Welding Prize Contest

It was voted that the AMERICAN WELDING SOCIETY accept sponsorship for the judging and awarding of cash prizes offered by the Summerill Tubing Company and, further, that rules governing this prize contest prepared by the Summerill Tubing Company, in consultation with President Jenks, be approved.

These prizes are being awarded in order to stimulate interest in papers dealing with the subject of aircraft steels including tubing and other steel parts for tubular assemblies.

Year Book

Consideration was given proposal of the Publications Committee for publication of the Year Book as a separate document from THE WELDING JOURNAL. It was the consensus of opinion it is highly desirable that the Year Book be so published.

Outline of Work Committee Recommendations

The following appointments were approved.

Committee on Preparation of Recommended Practices for Inspection of Welding: addition of Everett Chapman with W. C. Theisinger as alternate, to represent the American Iron & Steel Institute.

A. W. S. Representative on A. P. I. Committee on Field Welding of Casing: replacement of A. E. Marble of Jones & Laughlin Steel Corporation by L. Van Ormer of the same corporation.

Committee on Welding in Marine Construction: replacement of C. W. Bryan, Jr., Federal Shipbuilding and Dry Dock Company by B. A. Russell of the same company.

Membership Dues Payment

A revision of the By-Laws is being considered, and, in the interim, Headquarters was authorized to accept a full year's dues from new members until action is taken on the proposed amendment by the By-Laws Committee.

1941 Nominating Committee

The President advised that he had appointed a committee composed of H. C. Boardman, *Chairman*, J. J. Crowe, C. H. Jennings, J. F. Lincoln, P. D. McElfish, G. Raymond, J. D. Tebben. He asked for confirmation of this appointment.

The President's selections were approved.

WELDING SCHOOL BOOKLET

The Champion Rivet Company are issuing a 16-page booklet entitled "Electric Arc Welding" dealing with the simple and fundamental facts of welding. Designed primarily for the student welder, it is being distributed gratis to private and public training institutions where welding is being taught.

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DISTRICT VICE-PRESIDENT

Due to a business change, Mr. O. T. Barnett, District Vice-President of the Southern District, no longer resides in that district as he is now connected with the Metal & Thermit Corporation in their Jersey City office. It, therefore, became necessary to elect a District Vice-President to serve the Southern District. As a result of a letter ballot sent out by Acting Secretary Banks, Mr. J. A. Hall of the Kansas City Structural Steel Company, was elected Vice-President representing the Southern District for the unexpired term of Mr. Barnett.

TENTATIVE PROGRAM OF FIRST NEW ENGLAND WELDING CONFERENCE TO BE HELD AT MASSACHUSETTS INSTITUTE OF TECHNOLOGY APRIL 25 AND 26, 1941

Friday, April 25th

9:00 A.M. Registration
9:45 A.M. Address of Welcome.
10:00 A.M. Technical Session.
Chairman: Col. G. F. Jenks, President, AMERICAN WELDING SOCIETY.
"Modern Applications of Flame Cutting Processes," J. H. Zimmerman, Development Manager, The Linde Air Products Co., New York, N. Y.
"Weldability of Steels," W. G. Theisinger, Director of Welding Research, Lukens Steel Co., Coatesville, Pa.
12:30 P.M. Luncheon—Walker Memorial.
Movie of World's Largest Plate Mill in Operation. Courtesy of Lukens Steel Co. Shown by W. G. Theisinger.
2:00 P.M. Technical Session.
Chairman: R. S. Williams, Department of Metallurgy, M. I. T., Cambridge, Mass.
"Welding in Machine Design," J. H. Cooper, Welding Engineer, Taylor-Winfield Corp., Warren, Ohio.
"Welding of Copper and Red Brass," J. Babin, Engineer, Sales Promotion Division, Chase Brass & Copper Co., Waterbury, Conn.
Discussion by J. J. Vreeland, Metallurgical Engineer, Sales Division, Chase Brass & Copper Co., Waterbury, Conn.
Demonstration by F. A. Gallo, Chase Brass & Copper Co., Waterbury, Conn.
6:00 P.M. Conference Dinner—Walker Memorial.
F. B. Mehaffey, Presiding, Assistant Sales Manager, Air Reduction Sales Co., Boston, Mass.
Program to be announced later.

Saturday, April 26th

9:00 A.M. Registration.
10:00 A.M. Technical Session.
Chairman: Paul D. Ffield, Materials Engineer, Bethlehem Steel Co., Shipbuilding Division, Quincy, Mass.
"Developments in Resistance Welding," W. F. Hess, Department of Metallurgy, R. P. I., Troy, N. Y.
"Welding of Steel Structures," LaMotte Grover, Structural Welding Engineer, Air Reduction Sales Co., New York, N. Y.
12:30 P.M. Luncheon—Walker Memorial.
Movie on Structural Welding. Courtesy of Air Reduction Sales Co. Shown by LaMotte Grover.
2:00 P.M. Technical Session.
Chairman: P. J. Horgan, Engineer, Turbine Department, General Electric Co., Lynn, Mass.
"Inspection of Fusion Welds," Edwards R. Fish, Chief Engineer, Boiler Division, Hartford Steam Boiler Inspection and Insurance Co., Hartford, Conn.
"Qualification of Welders," R. W. Clark, Welding Engineer, Works Laboratory, General Electric Co., Schenectady, N. Y.
5:00 P.M. Annual Meeting of Boston Section of the AMERICAN WELDING SOCIETY.

TENTATIVE PROGRAM WELDING CONFERENCE

There follows a Tentative Program of the two-day Welding Conference at Michigan State College, East Lansing, Michigan. The Detroit Section of the AMERICAN WELDING SOCIETY is cooperating in the arrangements of the program.

The Welding Engineer Says . . .

"Between Mallory Alloys and Mallory Standardization 'Down Time' has been reduced to an absolute minimum."

Mallory's program of welding electrode standardization has improved welding practice in several directions simultaneously. First, it has assisted in the development of the highest efficiency in the electrodes themselves. They provide more welds between redressing . . . and a greater total number of welds before replacement is necessary. Second, Mallory standardization has eliminated costly delays in waiting for special orders to be completed.

Mallory's standardization program has been based upon years of closest cooperation with the leading welding machine manufacturers . . . plus the most exhaustive experimental and research work. The leadership that this policy has won for Mallory Welding Electrodes is being jealously protected by a continuance of this same extensive development work. Mallory never takes leadership for granted.

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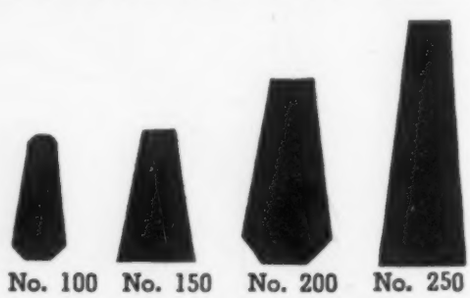
11 to 13½% Manganese Nickel Steel
SPECIAL SHAPE APPLICATOR BARS



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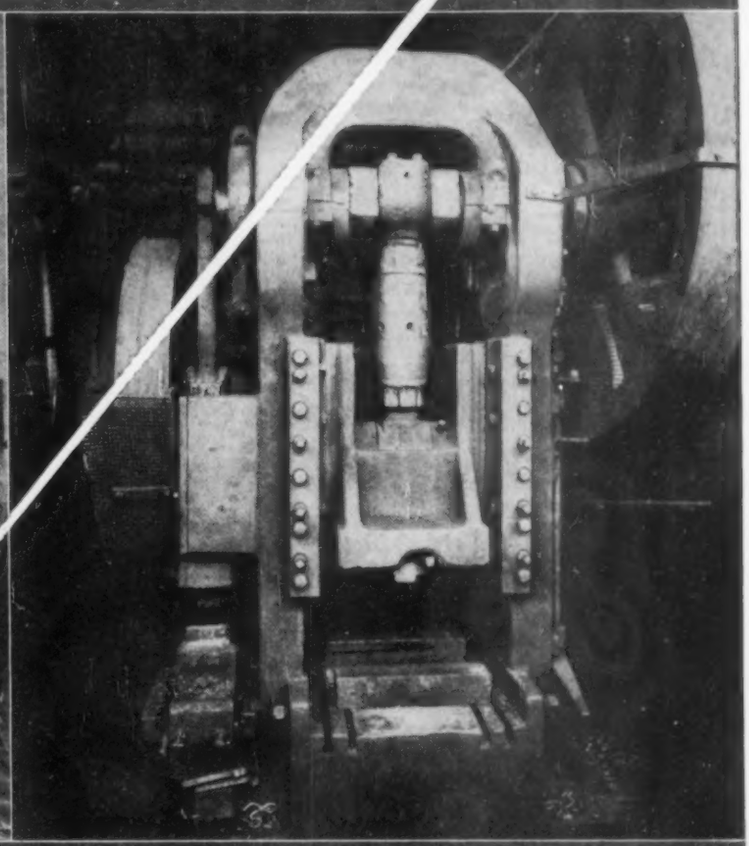

IN 46 HOURS!

Thanks to Anaconda 997 Low Fuming Welding Rod

WHEN the Hebeler Welding Company of Buffalo, New York, were called in on this emergency job, they took one look at the fractured 4½-ton punch press; promptly recommended repair welding with Anaconda 997 Low Fuming Rod . . . a high strength, tough weld metal with low fuming characteristics.

The job consumed 160 pounds of filler rod and 1,600 feet of both oxygen and acetylene. Chipping, preheating with natural gas and compressed air and other preparation required 35 hours; welding, 11 hours. The result was a strong sound weld and a happy production manager, for the downtime loss was only a fraction of what he expected.

Next time you're faced with a similar emergency, bear this story in mind. Anaconda Rods are produced in an extensive line of alloys for all kinds of welding. You can obtain them from your jobber. 40119

ANACONDA from mine to consumer

Anaconda Welding Rods

THE AMERICAN BRASS COMPANY, General Offices: Waterbury, Connecticut

In Canada: Anaconda American Brass Ltd., New Toronto, Ont. • Subsidiary of Anaconda Copper Mining Company

Friday, April 25th

9:30 A.M. Opening Session
Address of Welcome, H. B. Dirks, Dean of Engineering, M. S. C.
Reply, K. L. Hansen, 1st Vice-Pres., A.W.S.
"Atomic Hydrogen Welding," L. G. Pickhaver, General Electric Co.
"Metallurgy of Weld Metal," F. R. Hensel, P. R. Mallory Company.
12:30–1:45 P.M. Luncheon on Campus
2:00 P.M. National Defense Program
"Electronic Controls," E. H. Vedder, Westinghouse E. & M. Company.
"Welding of Aluminum," G. O. Hoglund, Aluminum Company of America.
"Welding of Stainless Steels."
5:30 P.M. Tour of Campus by Bus
7:15 P.M. Dinner—Union Building

Saturday, April 26th

9:30 A.M. Resistance Welding Session
"Maintenance of Resistance Welding Machines and Electrodes," G. N. Sieger, S-M-S Corporation.
"Stored Energy Resistance Welders and Their Place in the Defense Program," S. M. Humphrey, Taylor-Winfield Corporation.
"Pulsation Welding," H. C. Cogan, National Electric Welding Machines Co.
12:00 Noon Luncheon—Union Building
1:30 P.M. Afternoon Session
"Designing for Arc Welding," H. C. Hettelsater, Harnischfeger Corp.
"Flame Hardening & Strengthening," R. F. Flood, Linde Air Products Co.
"Aircraft Welding," Frank Smith, Stout Skycraft, Inc.

LAMME MEDAL AWARDED

Dr. C. A. Adams to Receive Honor of Electrical Engineers

The Lamme Medal of the American Institute of Electrical Engineers, not given since 1938, has been awarded to Dr. Comfort Avery Adams, consulting engineer, Edward G. Budd Manufacturing Company, Philadelphia, "for his contribution to the theory and design of alternating current machinery and his work in the field of electric welding."

The medal and certificate will be presented to Dr. Adams at the annual summer convention of the Institute, to be held in Toronto, Canada, the week of June 16th to 20th. Dr. Adams was born at Cleveland, Ohio, November 1, 1868, and received the degree of bachelor of science in 1890 from the Case School of Applied Science and that of electrical engineer in 1905 from Harvard University. He also received the honorary degree of doctor of engineering from Harvard in 1925, and from Lehigh University in 1939. During the summer of 1890 he went with the Reid Expedition to Alaska making magnetic and meteorological observations. He became an instructor in electrical engineering at Harvard University in 1891 and continued as a member of the Harvard faculty, as assistant professor, 1896–1906, professor, 1906–16, Lawrence professor of engineering, 1914–36, dean of the engineering school, 1919–21. Upon his retirement from teaching in 1936, he was made professor emeritus. In addition to teaching, he carried on an extensive consulting practice on which he has concentrated since 1930. In addition to the Budd company, his connections include the Babcock and Wilcox Company, Okonite Company, and others. He has served the American Institute of Electrical Engineers as a manager (1912–15), vice-president (1915–17), and president (1918–19), and as member or chairman of many committees, and has represented the Institute on various bodies. He was one of the organizers and first chairman of The American Engineering Standards Committee, from which the American Standards Association grew. He was the first president of the AMERICAN WELDING SOCIETY, and is also a member of the American Academy of Arts and Sciences, American Association for the Advancement of Science, American Physical Society, Society for the Promotion of Engineering Education, American Society of Civil Engineers, American Society of Mechanical Engineers, American Society of Testing Materials, and of several foreign technical societies.

Dr. Adams is an Honorary Member of the AMERICAN WELDING SOCIETY, recipient of the Samuel Wylie Miller Medal, and Chairman of the Society's Research Committee since the inception of the Society.

Just ONE set-up for every weld

Save valuable time in welding, handling; do better "downhand" welding—all with more safety, by using a C-F Positioner. Cut down crane service on large unwieldy work by "setting-up" just once for all welds. C-F Positioners are made in hand and power operated models with a variety of control features suitable for all kinds of work. Send coupon today for complete information about these remarkable welding machines which give every advantage to today's production demands.

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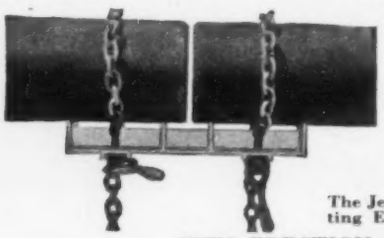

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Light—Adjustable—Fast

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Keeps the Welder Welding Instead of Waiting

JEWEL MANUFACTURING COMPANY
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REG. U.S. CASTOLIN PAT. OFF.

Eutectic Alloys
For LOW TEMPERATURE WELDING

Fast — Easy — No over-heating — No distortion — No stresses — Properties unaffected — Improves production
Saves valuable castings.

FOR EVERY METAL A EUTECTIC ROD:
For Aluminum and Alloys, Brass, Bronze and Copper, Cast iron, Malleable Steel and Stainless, Nickel and Monel, Magnesium, (Dowmetal), Die castings, Tungsten-carbide, Diamond setting.

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EUTECTIC WELDING ALLOYS, INC.
40 WORTH STREET NEW YORK, N. Y.

Economy AND EQUIPMENT

MEMBER COMPANIES

Taylor-Hall Welding Corporation, Worcester, Mass.
Taylor-Winfield Corporation, Warren, Ohio
Thomson-Gibb Electric Welding Co., Lynn, Mass.
Welding Machines Mfg. Co., Detroit, Mich.
Acme Electric Welder Company, Huntington Park, Calif.
Eisler Engineering Company, Newark, N. J.
Expert Welding Machine Co., Detroit, Mich.
Federal Machine and Welder Company, Warren, Ohio
Multi-Hydromatic Welding and Manufacturing Co., Detroit, Mich.
National Electric Welding Machines Co., Bay City, Mich.
Progressive Welder Company, Detroit, Mich.
Swift Electric Welder Company, Detroit, Mich.

ASSOCIATE MEMBER COMPANIES

S-M-S Corporation, Detroit, Mich.
Electroloy, Inc., New York City
Welding Sales and Engineering Co., Detroit, Mich.
P. R. Mallory and Co., Indianapolis, Ind.

ECONOMY as a motivating factor in prompting the replacement of obsolete industrial equipment has become secondary to today's all-important need for speed. Yet, present production schedules have sharply enhanced the desirability of modern equipment from a strictly economical standpoint. Certainly the operation of outmoded machines 24 hours a day and 7 days a week without full return and while paying overtime is an increasingly uneconomical practice.

Drastically reduced fabrication costs with Resistance Welding are an outstanding example of the production economy of modern methods.

RESISTANCE WELDER MANUFACTURERS ASSOCIATION • RWMA

Consult any of the member companies listed here. They have experienced engineers available who can show you what results Resistance Welding can accomplish in your plant.

RESISTANCE WELDER

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505 Arch Street • • • Philadelphia, Pa.

WELDING CONFERENCE, UNIVERSITY OF KANSAS

The School of Engineering of the University of Kansas, in cooperation with the Kansas City and Wichita Sections of the AMERICAN WELDING SOCIETY, will conduct a two-day Welding Conference at the University on April 25th and 26th. The newer developments in welding will be presented both in theory and practice. The program will be of special interest to structural and architectural workers in the area.

OBITUARIES

Albert Moulder

Albert W. Moulder, Vice-President of the General Fire Extinguisher Company and of the Grinnell Company, Inc., and an authority on steam and water piping, died February 11th at Jane Brown Memorial Hospital after an illness of less than a week. His residence was at Waterway, Barrington, R. I.

Mr. Moulder had been associated with the General Fire Extinguisher Company and its affiliate for the past 30 years, formerly at Warren, Ohio, and for the past 11 years in this city.

Albert Moulder

He was author of a number of books and engineering papers on heating and power and process piping and was known throughout the country as a pioneer in hot water heating and an authority on industrial piping problems.

Mr. Moulder was born in Adrian, Michigan, 52 years ago, a son of the late Albert and Louisa Brazin Moulder.

He was a member of the American Society of Mechanical Engineers, the American Society of Heating and Ventilating Engineers, the AMERICAN WELDING SOCIETY, the Providence Engineering Society and the Rhode Island Country Club, Turks Head Club and the Uptown Club of New York.

He is survived by his wife, Mrs. Lena Grafton Moulder; two daughters, Mrs. E. W. Easton of Albany, N. Y., and Mrs. W. Alexander of Princeton, N. J., and two grandchildren.

James E. Ferguson

James E. Ferguson, 65, manager of the fabricating division of The Austin Company, Cleveland, for the past 21 years, died March 3rd in a Cleveland hospital after a very brief illness.

Mr. Ferguson was born in Marshall, Michigan, and attended Cornell University, graduating with a degree in civil engineering in 1897. Prior to his joining The Austin Company in 1920, he had served as production manager of the Toledo Bridge & Crane Company, and as plant manager of the American Steel Car Company, Havana, Cuba.

He was a member of the AMERICAN WELDING SOCIETY and the American Society of Civil Engineers which had honored him recently with a life membership.

William Trefor Morgan

Mr. Morgan was born May 27, 1895, in Swansea, Wales. He attended the Swansea Technical College, Sheffield University at Sheffield, England, where he studied under Professor C. H. Desch, one of the outstanding metallurgists of the world. His academic career was interrupted by the first World War, in which he served five years, four of them on active service in France, Egypt and Palestine.

After the war he was associated with R. D. Thomas & Co., steel and tinplate manufacturers in Swansea, then joined the Department of Scientific Research of the British Admiralty where he spent six years.

After coming to this country he was associated with Babcock & Wilcox of Bayonne, N. J., and on August 5, 1929, came to the Taylor Instrument Companies. There he assumed charge of the metallurgical laboratory and has served as chief metallurgist ever since.

William Trefor Morgan

He was a member of the American Institute of Mining and Metallurgical Engineers, The Iron and Steel Institute of Great Britain, the AMERICAN WELDING SOCIETY and was a Past Chairman of the Rochester Chapter of the American Society for Metals which he was instrumental in developing.

Mr. Morgan leaves his wife and daughter, and his mother and six sisters in England. His death is a severe loss to the company and to his profession.

John D. Tierney

John D. Tierney, President of the Storts Welding Co., Meriden, Conn., died on February 25, 1941. Mr. Tierney was born on March 29, 1890. He began his career in the Middle West in the sales and advertising field. He became proprietor of Storts Welding Company in 1925. He was one of those who early saw the possibilities of welding in production and in developing and expanding the business of the Storts Welding Company. He wisely placed all emphasis on quality workmanship, setting up standards of fabrication from which no deviation was ever permitted. He was an active and useful member of the AMERICAN WELDING SOCIETY throughout his activity in the industry, always willing to contribute to the general knowledge of the art from his own experience and observation. His business life was ardently devoted to the building up of friendship in business. In his own organization he was held in high regard on account of the sincere personal interest which he showed in the welfare of all of his associates and employees. Those who knew Jack Tierney even casually esteemed him highly for these aspects of his leadership and even more for his complete devotion to his family. Mr. Tierney is survived by his widow, Rachel Valentine, by three daughters, Jean L., Merna M. and Sally M., and a son, John D. Tierney, Jr.

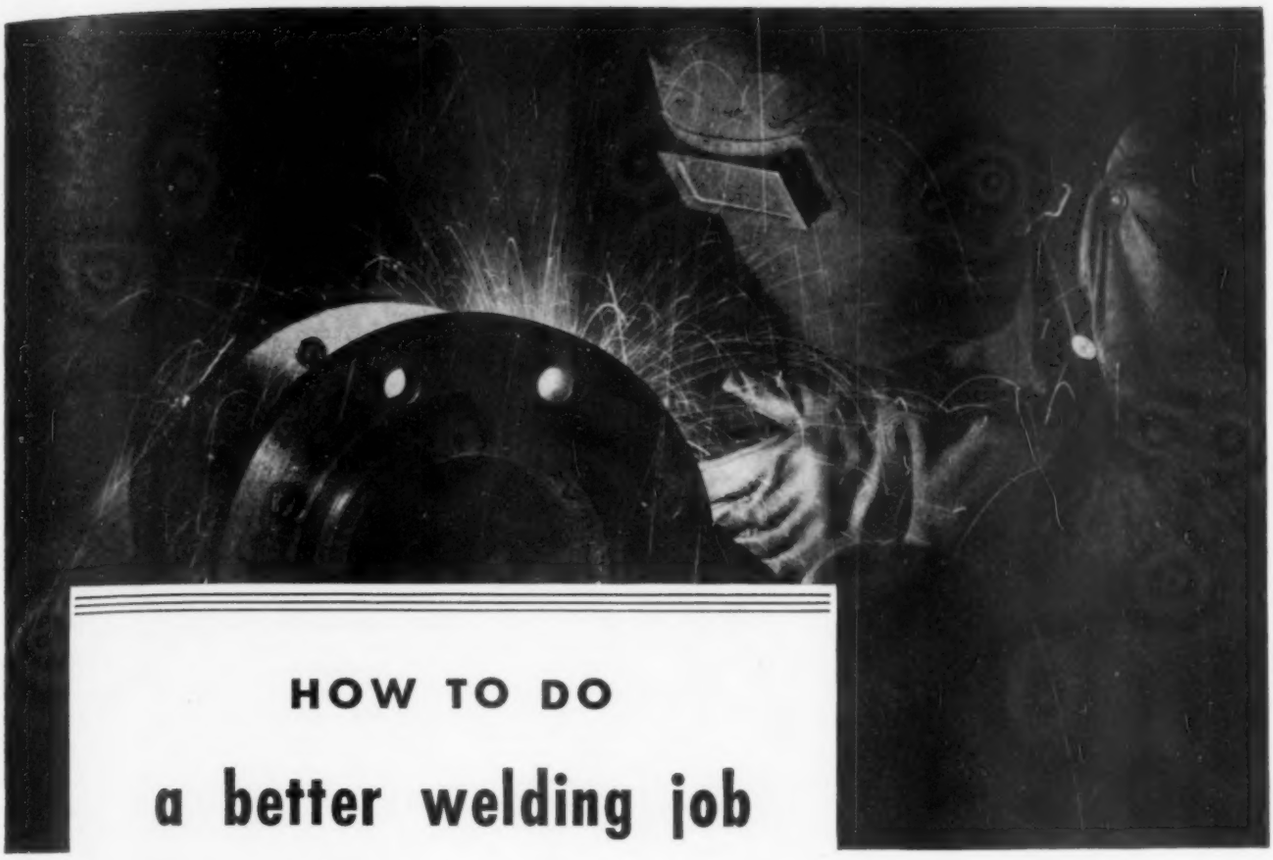
WELDING RODS

The new Chase Welding Handbook, Waterbury, Conn., outlines the more recent advances made in the art of welding copper and copper base alloys by both the oxyacetylene and carbon-arc methods. It also includes a description of each welding rod together with its advantages and suggested uses.

This book is available to our readers, free of charge.

FEDERAL GOVERNMENT STILL SEEKS JUNIOR ENGINEERS

Because of the increasing need for engineers in national defense work, the United States Civil Service Commission has again announced an examination to fill junior engineer positions in any branch of engineering. The salary is $2000 a year less a 3½ per cent retirement deduc-



HOW TO DO

a better welding job with these better steels

THE great variety in kinds and properties of U·S·S Rolled Steels we offer for welded construction carries with it an obligation we gladly assume. It accounts for our development of a welding engineering service designed to iron out your welding difficulties.

We are so confident we can help you improve welding construction by this combination of product and service that we will gladly match our time against yours in planning for your next job. We'll not only show what advantages can be gained through the use of U·S·S Rolled Steels, we'll show you how to go about it to effect them.

Today, when problems are bound to arise in the substitution of one kind of steel for another, or new designing calls for a kind of steel with which you are unfamiliar, ask for our assistance. We'll gladly cooperate. We not only make U·S·S Rolled Steels of any needed kind, but through wide experience we know their welding characteristics and requirements and will be pleased to share this knowledge with you. Write for more complete information.

Here are some of the U·S·S Rolled Steels which are contributing much to efficient and economical welded construction.

U·S·S Cor-Ten to resist corrosion.

U·S·S Man-Ten and **Cor-Ten** for weight reduction and corrosion resistance.

U·S·S Abrasion-Resisting Steel for use where abrasive conditions are severe.

U·S·S Heat-Resisting Steels to combat high temperatures.

U·S·S Stainless Steel to resist corrosion of all kinds and reduce structural weight.

U·S·S Carilloy Alloy Steels to carry tremendous bearing pressures.

U·S·S ROLLED STEELS *for* WELDING

CARNEGIE-ILLINOIS STEEL CORPORATION, *Pittsburgh and Chicago*
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United States Steel Export Company, New York

UNITED STATES STEEL

tion. Applications will now be rated as received at the Commission's Washington office until December 31, 1941. Qualified persons who do not have eligible ratings under previous junior engineer examinations held by the Commission within the past year are urged to file their applications at once.

Appointees will perform professional engineering work including assisting in experimental research, design or testing of machinery, and testing and inspection of engineering materials. Separate employment lists will be established in each recognized branch of engineering.

Competitors must have completed a 4-year engineering course, except that senior students will be admitted under certain conditions. They will not have to take a written test, but will be rated on their education and will be given additional credit for graduate study in engineering or for engineering experience.

Further information and application forms may be obtained from the Secretary of the Board of U. S. Civil Service Examiners at any first- or second-class post office, or from the U. S. Civil Service Commission, Washington, D. C.

WESTERN METAL CONGRESS

LOS ANGELES
May 19 to 23, 1941

Outstanding Technical Program

Largest Metal Exposition including Welding held in the West

See Detailed Program Elsewhere in Journal

Plan to Attend

BALL BEARING SWING JOINT

The 36-inch ball bearing swing joint, shown below, is the largest ever manufactured by Chiksan Tool Co., Brea, California, and is probably the largest ball bearing swing joint ever built. This big joint built especially for a government project weighs 3087 pounds and turns on one hundred and twenty-eight 2-inch stainless steel balls arranged in two rows and turning in flame-hardened races.

The ball race retainer plugs, which were put on after the joint was completely machined, were welded in place so that the ball bearings were fed in through these plugs and were then sealed off against all further outside air or fluid.

UNIVERSITY OF CALIFORNIA EXTENSION DIVISION

The University of California Extension Division announces a course in Welding Design to be conducted by the Department of Mechanical Engineering as a part of the Engineering Defense Training Program now being sponsored by the U. S. Office of Education.

Purpose: To give specialized training in the design of welded structures, tanks, pressure vessels and machine frames to engineers.

Course Content: Welding processes and equipment; types of welded joints; strength; methods of designation on drawings; standard methods of connecting structural shapes; code requirements; design problems on structures, trusses, cranes, storage tanks, pressure vessels and machine frames.

Instructor: Milton Kosman, Estimating Engineer, Western Pipe and Steel Co., San Francisco, California.

Prerequisites for Enrollment: At least three years of college training in a recognized engineering curriculum including a course in strength of materials, or equivalent experience.

Expenses: There is *no charge* to the student. The expense of conducting the course is borne by the U. S. Government. The student must furnish his own textbook, slide rule and drawing instruments.

University Credit: No University credit is given. A certificate of completion is issued to the student upon satisfactory completion of the course.

Employment: Completion of the course carries no assurance that the student will obtain a new position, or a better position than he now holds.

Enrollment: Prospective students may enroll at the time of the first class meeting. Continuation of the class is dependent upon an enrollment of at least 15 qualified students.

COORDINATORS OF CONSTRUCTION INSPECTION NEEDED BY THE UNITED STATES MARITIME COMMISSION

The United States Civil Service Commission has announced an examination for construction inspection coordinator in the United States Maritime Commission. The salary is $3800 a year. Applicants may qualify in three optional branches: Hull, electrical and machinery. The maximum age limit is 65.

Applicants must have had 4 years of practical experience of at least journeyman mechanic grade on the construction or repair of ocean-going vessels. Successful completion of college study in naval architecture or any branch of engineering may be used for part or all of this general experience. An additional 4 years of experience in supervisory capacity is required. Two years of the total experience must have been gained in construction work on new vessels, while the remaining experience may have been on repair of ocean-going steel vessels.

Persons appointed will serve as head of the hull, electrical or machinery units of the inspection branch of the Maritime Commission. They will act as liaison officers between the home office and shipyards at which vessel construction is under way in order to establish and maintain uniformly high standards of construction and of equipment installation.

Applications will be rated as received at the Commission's Washington office until further notice. These positions are important in connection with the increased ship-building activity in the National Defense Program, and qualified persons are urged to apply at once. Further information and application forms may be obtained at any first- or second-class post office, or from the Civil Service Commission.

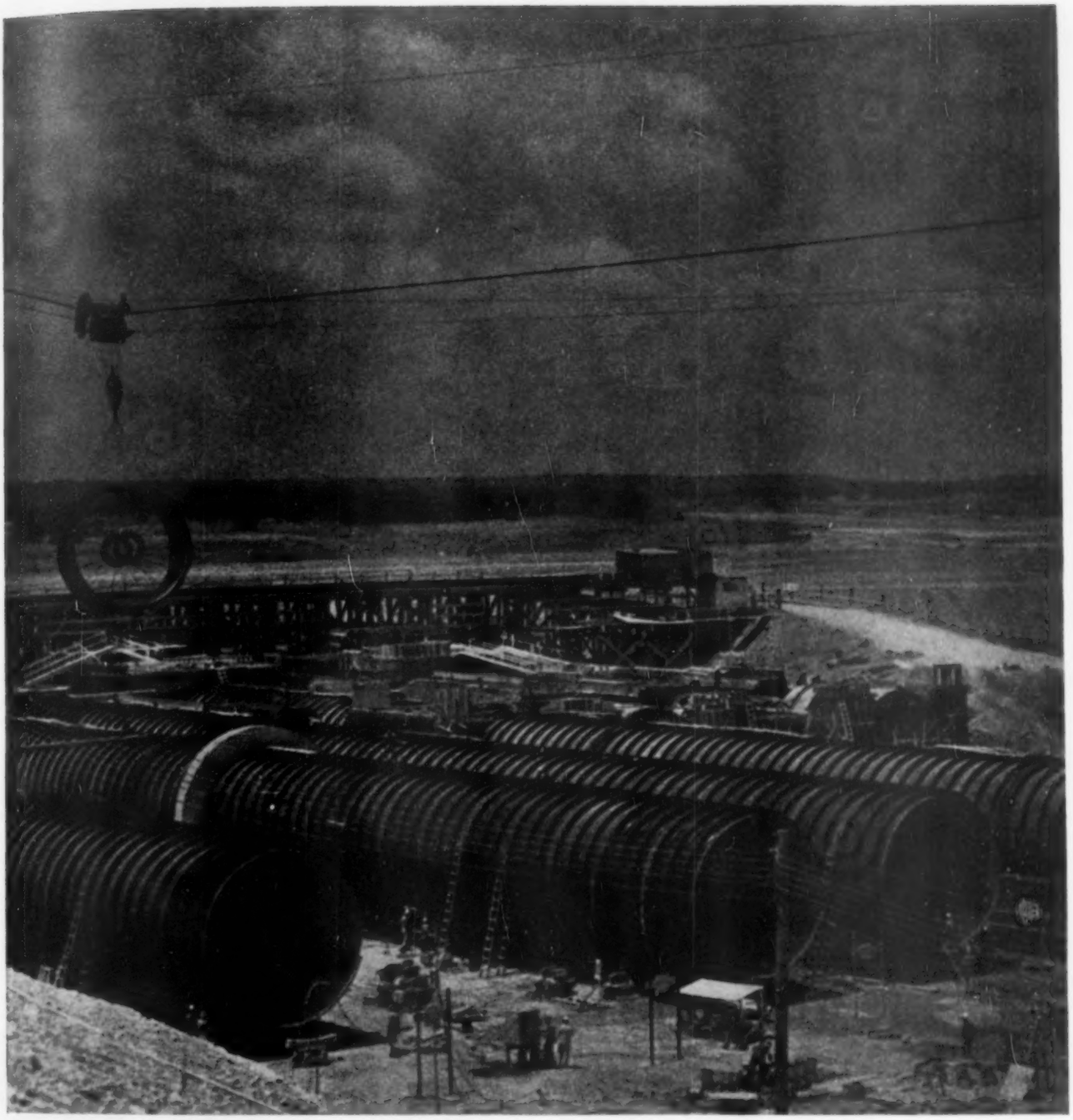
C. E. SWIFT JOINS AMPCO

Clinton E. Swift has become associated with the Weldrod Division of Ampco Metal, Inc., Milwaukee, Wisconsin, to head the development, production and distribution of Ampco-Trode, a complete line of coated aluminum bronze welding rods, made with the properties of Ampco Metal.

Mr. Swift has been associated with the welding industry since graduating from the University of Illinois, College of Engineering. He joined Westinghouse Electric and Mfg. Co. in 1929, where he worked on automatic arc-welding applications. In 1931 he became welding engineer for the American Brass Company, developing and applying copper alloy welding processes. Immediately preceding his present work he was welding engineer of C. F. Braun and Company, and welding superintendent at the Young Radiator Company. Mr. Swift is a member of the AMERICAN WELDING SOCIETY.

PIPE CUTTING SERVICE

A new pipe cutting service is announced by the Chicago Pipe Welding Co., 205 W. Wacker Drive, Chicago. They will furnish pipe cut to measure, with ends shaped, fitted and bevelled—all ready for welding by the customer. All cutting is done with exclusive cutting machines that produce smooth, clean, perfectly fitting intersections of any design, at any angle. An interesting illustrated circular will be mailed on request.



STEEL PENSTOCKS

. . . of welded construction

Although the field joints of this 20 ft. diameter steel penstock pipe were riveted, the many heavy circumferential reenforcing angles were welded in place in our shop. This made possible a simple, direct connection—an important money saver where a great many pipe sections had to be fabricated.

CHICAGO BRIDGE & IRON COMPANY

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New York	3398-165 Broadway Bldg.	Tulsa	1654 Hunt Bldg.	Boston	1565 Consolidated Gas Bldg.
Cleveland	2282 Builder's Exchange Bldg.	Houston	918 Richmond Ave.	San Francisco	1097 Rialto Bldg.
Dallas	1489 Praetorian Bldg.	Detroit	1556 Lafayette Bldg.	Los Angeles	1471 Wm. Fox Bldg.

Fabricating plants in CHICAGO, BIRMINGHAM and GREENVILLE, PA.

C. I. MacGUFFIE APPOINTED MANAGER GENERAL ELECTRIC, ELECTRIC WELDING SALES

Effective February 28th, C. I. MacGuffie has been appointed Manager Sales, Electric Welding Section of the General Electric Company, according to an announcement by J. E. N. Hume, Commercial Vice-President of the company. Mr. MacGuffie succeeds L. D. Meeker, now associated with the Smith-Meeker Engineering Company, New York City.

C. I. MacGuffie

A native of West Pittston, Pennsylvania, Mr. MacGuffie was graduated from Pennsylvania State College in 1925 with the degree of B.S. in Electrical Engineering. He immediately became associated with General Electric in its testing department at Schenectady, going to the company's Philadelphia office in 1928 to handle welding sales. In 1929, he was made Welding Specialist of the Atlantic District, and left Philadelphia for Schenectady in 1939 to become assistant to Mr. Meeker.

Mr. MacGuffie is a past chairman of the Philadelphia section of the AMERICAN WELDING SOCIETY. He is now a member of the Schenectady section of this society and an associate member of the A. I. E. E.

Mr. Meeker had been with the General Electric Co. since 1923 and manager of electric welding sales since 1930.

VICTOR CATALOGUE

The new 1941 Victor Catalogue has just been published. It is a handsomely illustrated booklet of 48 pages. It includes a complete description of the Victor Equipment line, including, regulators, torches, manifolds, gauges, connections and the like. Torches for every purpose are illustrated. The book contains some valuable technical data. Published by Victor Equipment Co., 844 Folsom Street, San Francisco, Calif.

GAS CUTTING IN MARINE CONSTRUCTION

Gas Cutting Machines for Marine Construction, a new 26-page bulletin issued by Air Reduction, New York, has been published to make available convenient descriptions of the various newly-developed machines for aiding fabrication by welding in the marine industry. Illustrative photographs display each of the machines and their functions in detail.

The machines described are the Airco Planographs, Polygraphs, Radiographs, Travographs and Beamographs. All are motor-driven gas cutting machines serving essential functions in marine applications—some for portable, some for stationary use. The bulletin describes these functions, explaining the use of the Nos. 4 and 10 Radiographs for cutting straight lines, arcs and circles and combinations of the two. A section is devoted to templet cutting, plate edge preparation and flame machining special operations which can be performed with these machines when simple attachments are used. The Nos. 1 and 10 Planographs, machines of the pantograph type for making excellent cuts in ferrous metal of any reasonable thicknesses, are described; also the No. 10 Polygraph for continuous cutting of shaped openings; the Travographs—the largest and most accurate of the Airco machines—for cutting an unlimited variety of shapes from steel plate, slabs, billets and forgings; the Beamographs for trimming the flanges and webs of beams. Where extra attachments are needed to perform special operations, similar information is included.

Copies of this bulletin may be obtained by writing Air Reduction, 60 East 42nd Street, New York, N. Y.

NEW ELEVATED WATER TANK BULLETIN

A new 20-page bulletin entitled "Radial-Cone Bottom Elevated Water Tanks" just issued by the Chicago Bridge & Iron Company contains illustrations of both structural and cylindrical column installations ranging from 125,000 to 2,000,000 gals. capacity. Although this design of water tank is most economical in capacities of 750,000 gals. or over, many waterworks engineers have found the advantages of appearance and low range in head sufficiently important to use it in smaller sizes.

The illustrations are arranged in the new bulletin so that it is easy to compare different construction features such as cylindrical or structural columns, cone or ellipsoidal roofs, curved or straight shells and spiral stairs and vertical ladders. A table of standard sizes is also included.

Copies of the bulletin will be sent upon request to waterworks engineers or waterworks officials.

BURR PROMOTED

Louis H. Burr, for 17 years production manager of The Austin Company's steel fabricating, division has been named works manager to succeed the late James E. Ferguson, according to George A. Bryant, president of the national engineering and construction organization.

Mr. Burr attended school in Toledo and was graduated from Denison University in 1906. He was structural superintendent of the Toledo Bridge & Crane Company at Toledo for some years and was associated with the Case Crane & Engineering Company immediately prior to joining The Austin Company as production manager in 1924.

Louis H. Burr

More than 50,000 tons of welded steel has been produced under the direction of Mr. Burr, who has had direct responsibility for fabrication of tree-form and other welded members applying Austin designs. He is a member of the AMERICAN WELDING SOCIETY.

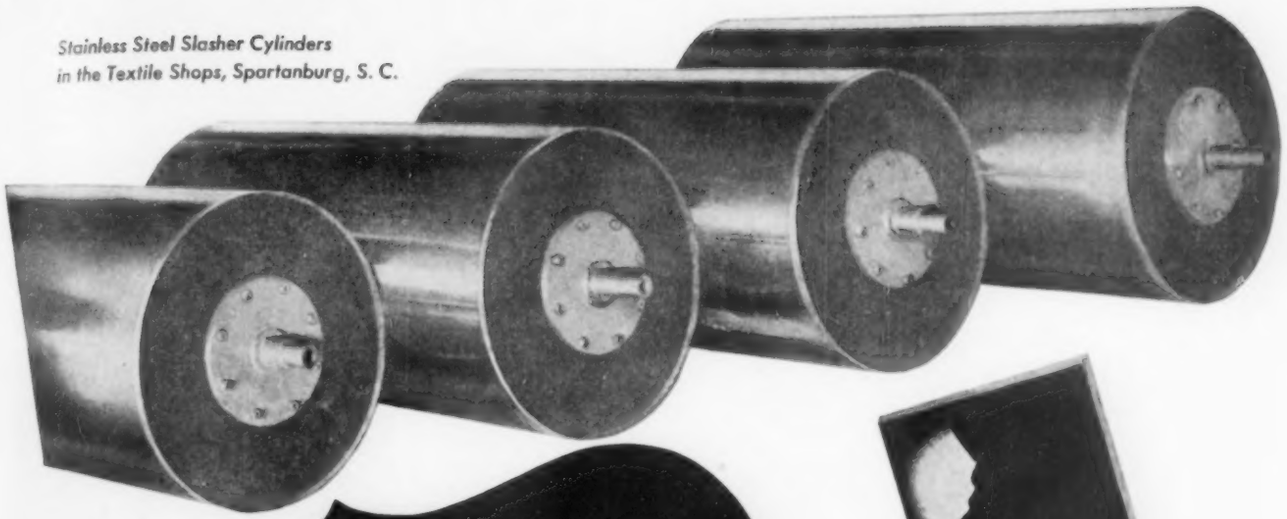
RECOMMEND RATING ARC-WELDING EQUIPMENT

The present rather arbitrary method of thermal rating of arc-welding equipment should be replaced with a logical method of rating based on actual service requirements.

This was the recommendation of R. C. Freeman and A. U. Welch of the General Electric Company in a paper titled, "The Service Factor Rating of Arc-Welding Generators and Transformers," presented January 30th at the winter convention of the American Institute of Electrical Engineers at Philadelphia.

The authors suggested the adoption of a current rating based on the load permissible in service, and adding a service factor to indicate the equivalent continuous load capacity so that heat tests can be made accurately and be duplicated easily.

Stainless Steel Slasher Cylinders in the Textile Shops, Spartanburg, S. C.



Page-Allegheny

STAINLESS STEEL ELECTRODES for your stainless welding

To make certain, when you weld Stainless, that the metal in the weld equals the metal you are welding, the first step is to tell your local PAGE Distributor the Stainless Analysis. He will provide the correct electrode—made by PAGE in cooperation with the world's largest producer of Stainless Steel.

These PAGE-Allegheny Stainless Steel Electrodes are for shield-arc welding and provide the high speed, low spatter and slag loss and smooth beads you want in all top quality welding. They are suitable for use on horizontal, vertical or overhead jobs.

Ask your local PAGE Distributor for the 12 page booklet on PAGE-Allegheny Electrodes. It contains valuable information to everyone welding Stainless Steel.

PAGE STEEL AND WIRE DIVISION
MONESSEN, PENNSYLVANIA

Ask your local PAGE Distributor for a copy of this booklet.

PAGE HI-TENSILE "F." A shield-arc type electrode for vertical, horizontal or overhead welding.

PAGE HI-TENSILE "C" A shield-arc type electrode for maximum strength, penetration and uniformity—vertical, horizontal or overhead welding.

In Business for Your Safety

PAGE ELECTRODES

PAGE STEEL AND WIRE DIVISION
MONESSEN • PENNSYLVANIA

AMERICAN CHAIN & CABLE COMPANY, Inc.

Occasionally, large errors in heating tests are caused by temperature drop in electrical insulation when measured by thermometer, it was pointed out. For measurements of winding temperatures, the use of the rise of resistance method was recommended as more likely to give accurate results.

IRON AND STEEL ENGINEERS MEETING

Plans are now being completed for the Annual Convention of the Association of Iron and Steel Engineers which will be held in Cleveland, Ohio, September 23rd, 24th, 25th and 26th, in the Cleveland Public Auditorium. Floor plans for the Iron and Steel Exposition, which is sponsored by the Association, have been released. The Exposition will be held in conjunction with the technical sessions of the annual convention, and will utilize over thirty thousand square feet for the display of the latest designs and products of the manufacturers of steel plant equipment.

A comprehensive technical program covering practically every branch of steel plant operations is being arranged and will be announced in detail shortly.

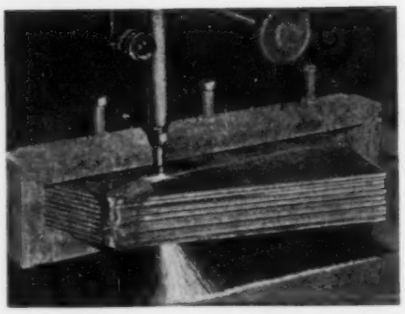
STULZ-SICKLES DISTRIBUTORS

The Stulz-Sickles Company, 134–142 Lafayette St., Newark, New Jersey, sole producers of MANGANAL, 11 to 13½% manganese-nickel steel, bare and Tite-Kote welding electrodes, applicator bars hot rolled plates, cast wedge bars, have appointed the following distributors: The Baum Iron Company, 13th and Harney Sts., Omaha, Nebraska; James C. Dawes Company, 24 North Fifth St., Martins Ferry, Ohio; The Faeth Company, 1127–31 West 8th St., Kansas City, Missouri; The Kacena Co., Cedar Rapids, Iowa; New York Welding Supply Co., 75 Grand St., New York City, New York; Sioux City Iron Co., Sioux City, Iowa; Velde, Roelfs & Co., 303–307 Margaret St., Pekin, Illinois.

DESURFACING AND STACK-CUTTING

Desurfacing.—The automatic desurfacing operation shown in the artist's drawing illustrates oxyacetylene desurfacing for the conditioning of semi-finished steel. Desurfacing machines, incorporated in the rolling mill, are used to remove defects

Fig. 1



Photos courtesy The Linde Air Products Co.
Fig. 2

from the material at rolling temperature, without interruption of the production cycle. This results both in increased production and improvement in the quality of the product (Fig. 1).

Stack-Cutting.—Oxyacetylene machine-cutting techniques, such as stack-cutting, enable the steel fabricator to turn out quickly a quantity of identical parts. The steel plates, or sheets, are stacked, clamped tightly together and cut as a unit in one cutting operation (Fig. 2).

LOCAL HOBART DISTRIBUTORS

Mr. H. F. Schotters has been appointed to supervise the distribution of Hobart Arc Welders in northern Indiana and western Michigan, with headquarters at Koontz-Wagner Electric Company, South Bend, Indiana. Local distributors appointed to date include C. H. Antrim, Grand Rapids, Michigan, Hoosier Oxygen Service, Fort Wayne, Indiana, and Bingrods, Incorporated, Kalamazoo, Michigan.

THE STORY OF AN ORGANIZATION

The Victor Equipment Company of 844 Folsom Street, San Francisco, Calif., has issued an attractive booklet under the above title. Two pages are devoted to the story of the welding industry. The remainder of the book is given over to the story of the Victor Equipment Company with attractive pictures of the many personalities that go toward making the Victor Company the success that it is. Each of the departments comes in for consideration. The method of handling the products of the Victor Equipment Company is clearly demonstrated.

SUPERINTENDENTS OF CONSTRUCTION NEEDED FOR DEFENSE WORK

An examination has been announced by the United States Civil Service Commission to secure superintendents of general construction for work in the national defense program. Broad and responsible experience is required, and qualified persons are urged to file their applications at the Commission's Washington office where they will be rated as received until December 31, 1941.

There are several grades of positions with salaries ranging from $3200 to $5600 a year, less a 3½ per cent retirement deduction. In general, the duties involve the direction of foremen, laborers and mechanics on large construction projects. Appointees will inspect materials and workmanship to see that they conform to specifications and will organize men and materials for efficient construction operations.

Competitors must have had progressive experience in the field of general construction. Part of this experience must have been as superintendent on large projects involving excavation, reinforced concrete, steel, wood and masonry, and supervision of three or more foremen of different building or construction trades. Engineering courses completed at a college or technical institute may be substituted for part of the general experience.

Further information and application forms may be obtained from the Secretary of the Board of U. S. Civil Service Examiners at any first- or second-class post office, or from the U. S. Civil Service Commission, Washington, D. C.

TWO UNIQUE BARGES BUILT IN BRAZIL

Shown in the accompanying illustration are two interesting barges recently completed for the Standard Oil Company in Brazil. They were built by Bonifacio Rodriques & Cia. Ltda. and are of all-arc-welded construction.

Photo courtesy The Lincoln Electric Co., Cleveland, Ohio

The barges are 90 feet long, 28 feet wide, 9 foot depth having a capacity of 3200 liters. They will be used in the transportation of gasoline, oil and kerosene.

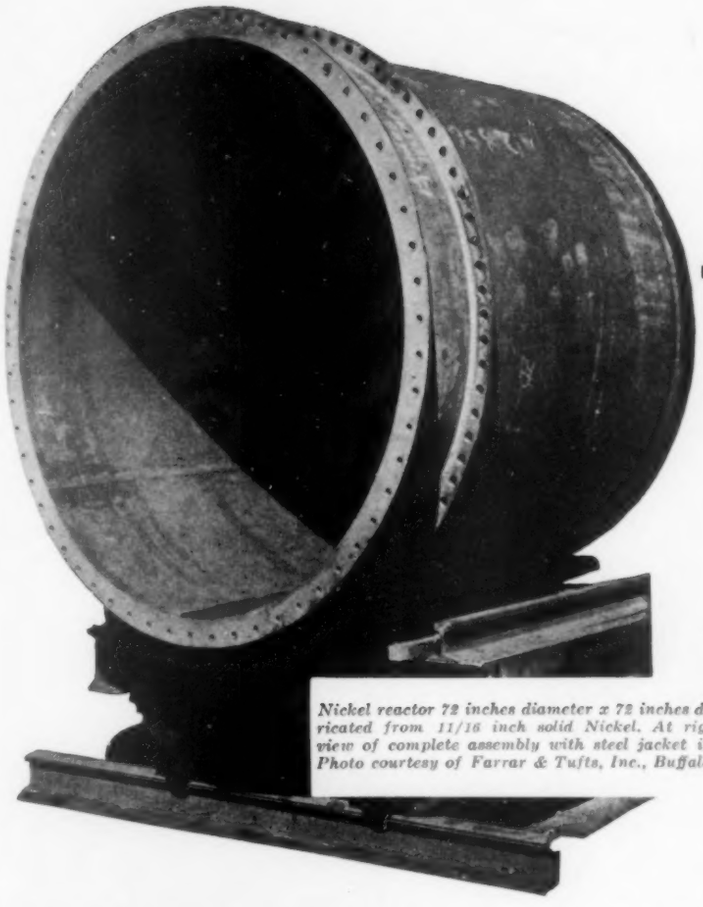
Construction by arc welding took 62 days and the cost of each vessel was $43,680. The builder is one of the leading companies in Brazil in construction of barges, tanks, reservoirs, tank cars and similar products.

LOW-TEMPERATURE WELDING AND BRAZING

Low-temperature welding and brazing fills the gap between high-temperature arc and acetylene welding and soft soldering.

The new Castolin Eutectic Welding Alloys are important for fabricating machine parts, tools in all metals, also correcting already machined castings. All this is possible due to their low temperatures and color-matching properties. A folder describing all Castolin Eutectic Alloys and giving interesting examples of applications will be sent, on request, by Eutectic Welding Alloys, Inc., 40 Worth Street, New York, N. Y.

Made of
SOLID NICKEL
...ALL-WELDED
Construction



Nickel reactor 72 inches diameter x 72 inches deep fabricated from 11/16 inch solid Nickel. At right is a view of complete assembly with steel jacket in place. Photo courtesy of Farrar & Tufts, Inc., Buffalo, N. Y.

Electric welded reaction vessel of Nickel plate 11/16 inch thick

A job to test a welder's mettle...and test the metal employed...is this solid Nickel reaction vessel. Made of 11/16 inch plate, it is built in accordance with A.S.M.E. code requirements.

What procedure was followed to assure strong, sound welds? First, the right rod was employed...No. 131 Nickel Arc Welding Rod. Second, before the job was started, test welds were made. Subjected to X-ray inspection, and to tensile and bend tests, they proved that both solid Nickel and weld metal were acceptable.

On jobs in Nickel or any of the Nickel-base alloys there's a way to assure easy welding and sound welds: Use the proper materials . . . as shown in the table below, and use the proper welding procedure. Write for new bulletin T-2 "Welding, Brazing and Soft Soldering of Monel, Nickel and Inconel." Address: The International Nickel Company, Inc., 67 Wall St., New York, N. Y.

PHYSICAL PROPERTIES OF TEST SPECIMENS

SPECIMEN	*Width and Thickness*	*Unit Load – P. S. I. Yield Strength*	*Ultimate*	*Elongation*	*Specific Gravity*
NICKEL PLATE	11/16 in. thick	44,000	73,600	40% in 8 in.	8.85
WELDED NICKEL JOINT No. 1	.645 wide x .614 in. thick	55,000	77,700		
No. 2	.637 wide x .611 thick	51,400	77,400		8.7
ALL WELD METAL	½ in. diam.	50,000	88,700	25% in 2 in.	
FREE BEND Face and Root				30% min. No fractures	
X-RAY	X-Ray pictures showed weld to be well within Code Requirement for porosity and to contain no slag inclusions or lack of fusion.				

INCO WELDING RODS and FLUXES

MONEL

Oxy-Acetylene . . . No. 40 Monel Gas Welding Rod—Monel Gas Welding Flux.

Metal Arc . . . No. 130-X Monel Metal Arc Welding Rod.

NICKEL

Oxy-Acetylene . . . No. 41 Nickel Gas Welding Rod—no flux is used.

Metal Arc . . . No. 131 Nickel Metal Arc Welding Rod.

INCONEL

Oxy-Acetylene . . . No. 42 Inconel Gas Welding Rod—Inconel Gas Welding Flux.

Metal Arc . . . No. 132 Inconel Metal Arc Welding Rod.

NICKEL-CLAD STEEL

Metal Arc . . . No. 135 Nickel Metal Arc Welding Rod.

NICKEL

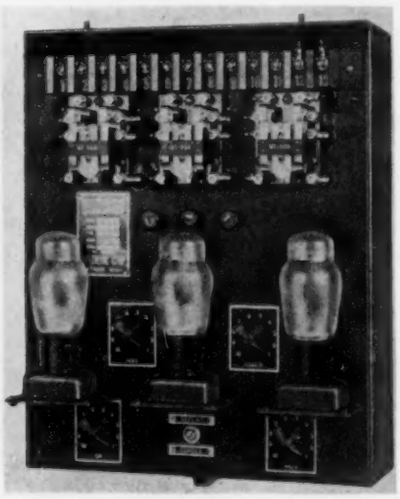
NEW PRODUCTS

The Society assumes no responsibility for the validity of claims in this Section

LOW COST TIMER

Designed to eliminate the necessity of an air or hydraulic pressure switch in resistance welding and to provide accurate timing control for any air-operated stationary or portable single or multi-spot welder, the Model 75 electronic tube-type timer is added to the line of Timers and Controllers manufactured by Weltronic Corporation, 3098 East Outer Drive, Detroit, Michigan.

Featuring a minimum of moving parts as well as eliminating the need of a pressure switch, the Model 75 insures a minimum of maintenance costs with down time being virtually eliminated, it is said.



Using a repeating timer to eliminate the need of a pressure switch requires one additional timing function. The four adjustments required are: "Squeeze" time, "Weld" time, "Hold" time and "Off" time. The "Squeeze" time is the interval between the instant the initial welding pressure is applied and the welding current is "on," which allows sufficient time to permit the full welding pressure to build up before welding current is applied. Thus, the timer will compensate for the effects of lowered room temperatures or extreme distance from pressure switch to welder and, it is said, insure uniform performance and better quality welds.

LINDE ANNOUNCES NEW CYLINDER TRUCK

A new hand truck designed to carry an oxygen cylinder, an acetylene cylinder and a complete welding and cutting outfit has just been announced by The Linde Air Products Company, a Unit of Union Carbide and Carbon Corporation. This new truck—known as the Oxweld T-7 Two-Wheel Welding Truck—is light in weight, well balanced and has 14-in. wheels equipped with semi-pneumatic rubber tires. The T-7 weighs considerably less than the former all-steel-wheeled trucks which it replaces.

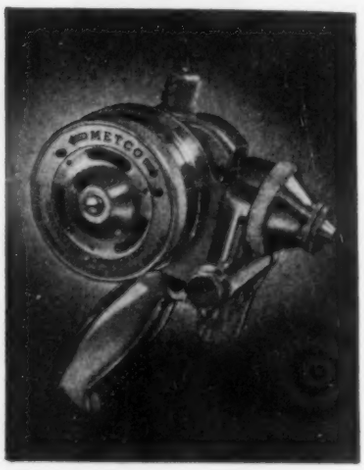
These features make the truck exceptionally easy to maneuver. It is easier to handle over rough places than trucks with even larger-diameter wheels. The new design results in a $4\frac{1}{2}$-in. reduction in over-all width of the truck, permitting passage through narrower openings. As an added feature, the size of the removable metal tool box, for extra blowpipes, tips, goggles and wrenches, has been increased.

TELLING THE WHOLE STORY ON THE LABEL

Introducing a brand new service idea to the welding industry, General Electric now places on each box of welding electrodes a "Production Label" here reproduced in giant size. Designed to help users, welding supervisors and stock clerks, the labels show the weight of deposited metal obtainable from the 50-lb contents of each box as well as the length of typical fillet welds that can be made. This new help is expected to make it easier for all concerned with welding processes to estimate costs and requirements, and to give welding operators standards or typical welds against which they may check their own results.

METALLIZING GUN

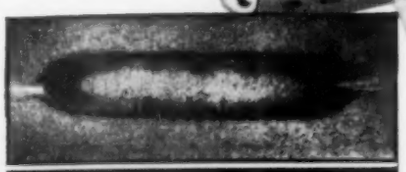
Operation: The metal wire is automatically fed into the gun at an adjustable speed, where it is melted by means of concentrated flame, atomized by compressed air and sprayed on any base material. The gun may be used as a hand tool for coating large structures with zinc, aluminum, lead or other metals, or as a lathe tool for building up worn shafts, rolls, plungers, etc., with steel, stainless steel, monel metal, bronze or any other metal obtainable in wire form.



Features: The Type 2*E* gun has two new outstanding features, the "Controlled Power Unit," which gives an absolutely uniform and steady wire feed for production service, eliminates the need for gear changes and the "Universal Gas Head" allows the use of acetylene, propane, hy-

GENERAL ELECTRIC
ARC WELDING
ELECTRODES
FOR MILD STEEL
ALL POSITIONS
TYPE W-20
SIZE 1/8" X 14"
STRAIGHT POLARITY or AC
SCHENECTADY, N. Y.
PRODUCTION DATA
This 50 lb. box of electrodes will produce 32.4 lb. of filler metal in joint, based on 2" stub ends.
Welding production is estimated as follows:

★ Micrograph (10 power) 24 S-T Alclad Sheet, two pieces, each 0.081" thick. Single spot shear, 1350 lbs.



★ Micrograph (10 power) 24 S-T Alclad Sheet, two pieces, each 0.064" thick. Single spot shear, 1100 lbs.

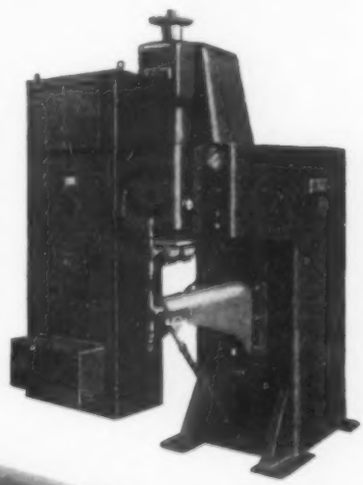
WELDED STRENGTH

IN EXCESS OF STANDARD SPECIFICATIONS

FEDERAL UNI-PULSE SPOT WELDERS, used extensively in the fabrication of sheet stainless and aluminum alloys, are a contributing factor of great importance in the mass production of aircraft. Micrographs of Uni-Pulse Spot Welds on various gage thicknesses of 24 S-T Alclad, as illustrated above, show consistent welding results with strength IN EXCESS of standard specifications. With Federal Uni-Pulse Spot Welders this difficult aluminum alloy fabrication problem is accomplished with greater efficiency and economy.

This improved method of welding stainless sheet and aluminum alloys employs electrostatic storage of energy and greatly reduces peak power demands, at the same time providing flexible control of the current wave form. As a result, life of the welding electrode tips is greatly increased and the weld nugget size and shape consistently accomplished. Federal Uni-Pulse spot welding, especially adaptable to the aircraft industry, will help you meet defense order demands ON TIME.

Federal Uni-Pulse Spot Welders of the "Press Type," shown here, are constructed with low inertia high speed patented head, and supplement Federal's conventional "Rocker Arm Type" Welders so predominant among leading aircraft manufacturing concerns.



In England, made by British Federal Welder & Machine Co. Ltd., Dudley, England

Federal MACHINE AND WELDER COMPANY WARREN, OHIO

SALES OFFICES IN ALL PRINCIPAL CITIES

drogen, natural or manufactured gas with balanced pressures and without changing heads.

In addition this gun has improved spraying characteristics. Extremely fine coatings are obtained at production speeds, and this, combined with simplified adjustments, permits continuous operation with maintained speed and quality. Improved nozzle and jet construction reduce gas consumption and result in the deposit of a maximum efficiency and economy. Lightweight, perfect balance and easy hand grip combine to eliminate operator fatigue. Maximum air pressure required is only 65 psi. Rugged in construction the Type 2*E* gun is ideal for heavy duty metal spray work.

For information write to Metallizing Engineering Co., 21-07 41st Ave., Long Island City, N. Y.

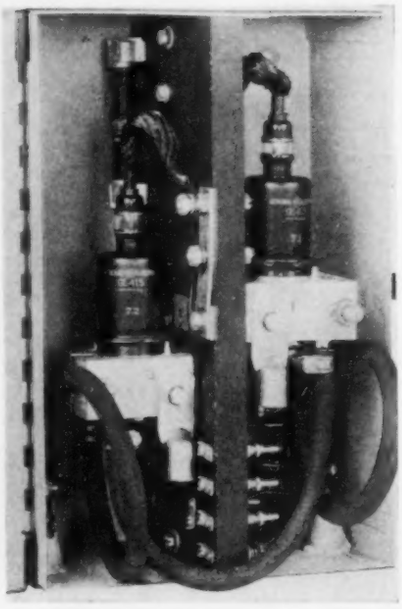
TRANSFORMER ARC WELDER

The Eisler Engineering Company of 740–770 South 13th Street, Newark, New Jersey, has recently placed a new model A.C. Transformer Type Arc Welder on the market. This machine is available from 100 to 400 ampere capacity. They are made standard to operate on 220 volts, 60 cycles, A.C., single phase, or any single phase of a polyphase circuit. Can be supplied for 440 or 550 volts at no extra cost.

A few of the outstanding features of this arc welder are: ease of striking and holding an arc due to a specially designed series reactor; simplicity of control; the value of current and size of welding rod to be used is clearly indicated for each dial setting; non-inflammable and heat-proof insulation; the welders are mounted on rubber covered swivel casters for moving easily from job to job.

GENERAL ELECTRIC INTRODUCES NEW IGNITRON TUBE

A new ignitron tube, Type GL-415, for resistance-welder control, utilizing a unique water-cooling system, has been announced by the General Electric Company. The new tube depends for its cooling upon a special clamp into which it is fitted, rather than upon the built-in water-jacket construction formerly used. Consisting of a brass block with water passages, the clamp not only serves as a cooling medium but also as the cathode connection. Since there are no water connections to the tube itself, removal and replacement of tubes may be made easily and quickly.

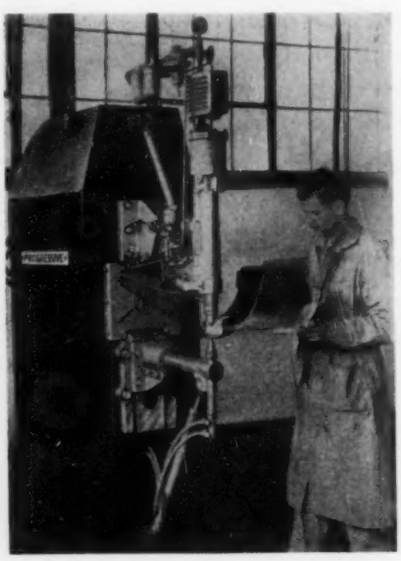


Ability to pass high-peak currents makes these ignitron tubes particularly suited for controlling the current of resistance-welding machines. Their sturdy metal construction, noiseless operation, and absence of moving parts, contribute to long life with a minimum of "down" time.

A pair of the tubes is capable of controlling 265 kva. of resistance-welding load on a $5^1/_2$ per cent duty cycle. They can be used at reduced rating with air cooling, when desired. With suitable control, the tubes can be used also for accurate, short-time welding.

NEW ALUMINUM WELDING METHOD

Progressive Welder Company, Detroit, manufacturer of welding and punching equipment, will demonstrate a new aluminum welding process in the company booth No. 370 at the coming A. S. T. E. Show.

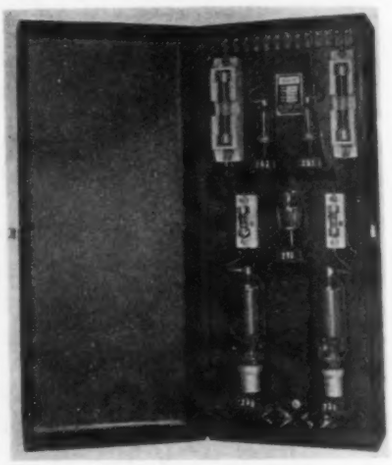


This new process employs a principle whereby 3-phase current can be utilized for the welding operation. This new method which has been under development at the Progressive plant for considerable time is extremely versatile. Company engineers state that it will weld ferrous and non-ferrous metals from very thin sheets up to quite heavy stock. A large number of machines can be used on a comparatively small power supply without overload. There are only two controls, one for pressure and one for heat. The machine is made of standard parts easily and economically replaceable.

ELECTRONIC SYNCHRONIZER

The Weltronic Corporation, engineers and manufacturers of precision control for resistance welding, located at 3080 East Outer Drive, Detroit, Michigan, announce a new development known as the Weltronic Synchronizer.

This device is designed to be used with any non-synchronous timer and power tube contactor to obtain synchronous operation by which is meant starting the



flow of electricity (current) at the zero point on the current wave, provided the wave form is approximately sinusoidal in character.

This eliminates the presence of transient currents and the resulting stresses and strains caused by these transients in welding transformers, making for much longer transformer life and in some instances allowing the use of smaller size transformers.

NON-SHATTERING SAFETY GOGGLE LENSES

Recently completed tests conducted by The Univis Lens Company, Dayton, Ohio, on their new Tulca Safety Goggle Lenses, have just been announced.

Officials of the company say that these tests have definitely proved that, under impact, Tulca lenses show greater uniform strength than the finest grade of tempered glass lenses ordinarily used.

The results of the tests show that all Tulca lenses show resistance to impact to the end of the sixth impact, which con-

sisted of a 3-ounce weight being dropped from a height of 54 inches.

Tulca lenses are made of a new type of non-shattering material and have all the safety properties inherent in safety glass lenses, yet lack many of the weaknesses common to the ordinary "safety" lenses.

TECHNOLOGISTS NEEDED BY THE GOVERNMENT

The U. S. Civil Service Commission has announced an open competitive examination to secure technologists for National Defense work. Difficulty is being experienced in filling positions in such branches of technology as explosives, fuels, plastics, rubber, minerals and textiles. Persons qualified in these branches are particularly urged to file application. Applications will be rated as received until *December 31, 1941*.

The duties of the positions include the planning, conducting and reporting of investigation or research in some specialized branch of technology such as explosives, fuels, plastics, rubber, minerals and textiles; or the testing, designing or manufacturing of the materials essential for the successful operation of an industrial plant where such plant operation is based on some specialized branch of technology. Applicants must have completed a 4-year college course with specialized major study except that they may substitute, year for year, for the required education, professional experience in the appropriate fields of science, engineering or technology. In addition, applicants must have had a certain number of years of professional experience in appropriate fields, the number of years varying with the grade of technologist; graduate study in an appropriate field may be substituted for a part of this experience.

The positions to be filled are in several grades with salaries ranging from $2600 to $5600 a year. Competitors will not be given a written test but will be rated upon their education and experience.

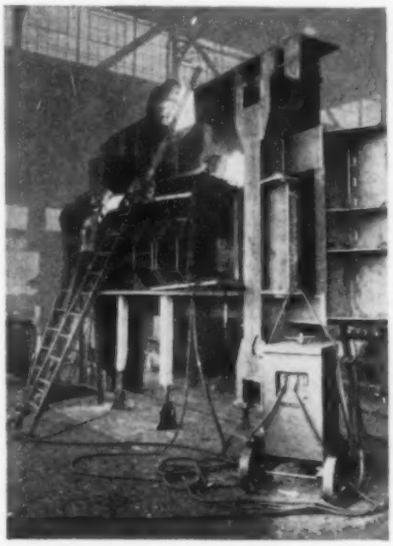
Further information and application forms may be obtained from the Secretary of the Board of U. S. Civil Service Examiners at any first- or second-class postoffice, or from the United States Civil Service Commission, Washington, D. C.

WELDED CRANE

The Photograph reproduced was taken in the plant of The Cleveland Crane & Engineering Company, Wickliffe, Ohio, and shows under construction what is believed to be the world's largest all-welded trolley frame for a heavy-duty Cleveland steel-mill type crane of 150-tons capacity.

The frame alone will weigh 32½ tons and have an over-all length and width of 23 feet 5 inches by 15 feet 6 inches. 276 pieces of various thicknesses varying from ⅜ inch to 2 inches are being welded together.

After the frame has been welded into a one-piece unit it will be accurately machined in the same manner as a huge casting. By machining the frame as a whole rather than in individual sections, perfect alignment and proper bearing seats and fits are assured.



The crane for which this trolley frame is being built is one of three duplicates to be used in connection with heavy defense work.

LOW-TEMPERATURE WELDING ALLOYS

The Eutectic Welding Alloys, Inc., 40 Worth Street, New York, N. Y., has just issued a new circular showing how to use Castolin Eutectic low-temperature welding alloys for all metals, and for improving designs for production welding, for salvaging blow-holed castings and for maintenance use. It is stated that this work can be done at very low temperature without melting parent metal or affecting size or metal structure itself. Copy of this circular may be obtained on request.

Employment Service Bulletin

SERVICES AVAILABLE

A-400. Welding Supervisor and Engineer. Graduate Engineer, past experience as research engineer, with Navy Department, in electric and gas welding procedures and techniques, handling of organic and mineral coated electrodes, alloy steel electrodes 18–8 (all classes), and other non-ferrous metals. Experience in welding metallurgy, handling X-ray equipment, hardness testing machines, tension and fatigue testing machines, etc. Seeking position as welding supervisor in either production or research and the training of men.

A-401. Arc Welder. Seeking a future in the industry. Three years' shop experience plus 3 years as sales demonstrator for welding machine manufacturer. Any location. Can travel. Age 35, married. Will prove to be worth consideration.

List of New Members

January 1st to January 31, 1941

BIRMINGHAM

Bagwell, M. W. (C), General Steel Tank Co., 4000 No. 8th Ave., Birmingham, Ala.
McBride, W. R. (C), P.O. Box 989, Montgomery, Ala.

BOSTON

Harding, Harry W. (C), Harding Welding Co., 8 Brooks Ave., Quincy, Mass.
Randlett, Haven F. (D), 34 Pine St., Riverside, R. I.
Renachan, Thomas J. (D), 2 Evelyn Ave., Malden, Mass.

CANADA

Raymond, C. E., 166 Eastbourne, Apt. 18, Toronto, Ont., Canada.

CANAL ZONE

Cannell, Paul J. (C), P.O. Box 53, Diablo Heights, Canal Zone.

CHICAGO

White, Charles (D), 6546 Woodlawn Ave., Chicago, Ill.

CINCINNATI

Jacoby, George A. (D), 1743 So. Derexa Dr., Hamilton, Ohio.

CLEVELAND

McCowin, Jack (D), 913 E. 140th St., Suite 1, Cleveland, Ohio.
Petersdorf, O. F. (D), 20198 Tracy Ave., Euclid, Ohio.
Ripley, Kenneth C. (D), 464 E. 117th St., Cleveland, Ohio.
Smith, Stanley (C), 1095—284 St., Wickliffe, Ohio.
White, Roger B. (C), 13515 Lake Shore Blvd., Cleveland, Ohio.

COLUMBUS

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Spangler, John I. (C), Read Machinery Co., 947 Virginia Ave., York, Pa.

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(*Continued on page 273*)

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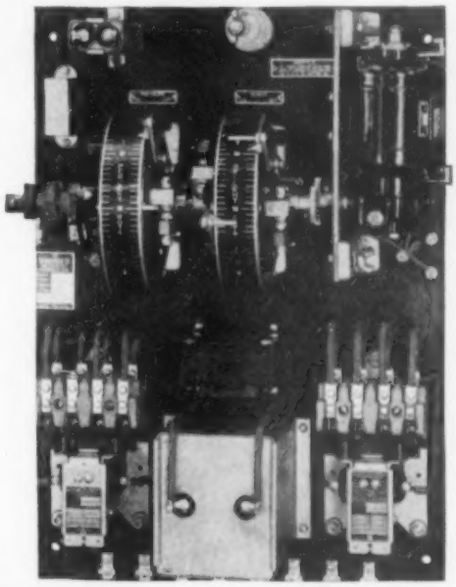

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SECTION ACTIVITIES

CHICAGO

The February meeting of the Chicago Section held on the 21st was addressed by C. J. Holslag of the Electric Arc Cutting and Welding Company, on the subject, "Pre-heating — Welding — Normalizing." The Smith-Dolan system of hysteresis heating of metals prior to, during and after welding holds many possibilities for the improvement of weld quality. On many metals preheating is a requisite for sound welding as is also normalizing of the weld metal after welding. Welding in below freezing temperatures is another problem handled by this system.

CLEVELAND

F. H. Frankland, Director of Engineering, American Institute of Steel Construction, Inc., New York City, and design consultant for many federal, state and municipal structures, also active in current structural operations in connection with national defense, addressed an intergroup meeting of 12 Cleveland engineering societies under sponsorship of the Cleveland section of the AMERICAN WELDING SOCIETY, Wednesday evening, March 12th, at 8 o'clock at the Mid-day Club. Mr. Frankland spoke on "Welding in the Building Industry" and illustrated his talk with lantern slides.

The meeting was preceded by dinner at 6:30 following which there was a brief talk entitled "Inspection of Naval Materials" by Capt. R. P. Schlabach, inspector of naval material and supervisor of shipbuilding, Cleveland district, U. S. Navy, who is stationed at the American Ship Building Co.

The board of experts for the April "Weldformation" meeting have been selected. They are: G. N. Sieger (master of ceremonies), Chairman of the Detroit Section; F. L. Plummer, Hammond Iron Works; J. C. Hodge, Wellman Engineering Company; E. W. P. Smith, Lincoln Electric Company; Robert E. Kinkead, consulting engineer.

COLUMBUS

The March meeting held on the 14th at the Fort Hayes Hotel was addressed by K. L. Hansen of Harnischfeger Corp. on "The Electric Arc as a Welding Tool." The regular meeting was preceded by a dinner.

DETROIT

The sixth meeting of the season of the Detroit Section was held on March 7th at the Detroit-Leland Hotel. Mr. G. S. Mikhalapov of Taylor-Winfield Corp. spoke on the subject, "Stored Energy Versus Condenser Discharge Method of Welding."

A meeting was held on April 4th at the Detroit Room of the Detroit-Leland Hotel. A talk was given by Mr. J. A. Weiger of the P. R. Mallory Co., Inc., on "Design and Care of Resistance Welding Electrodes."

There will be a welding clinic held at the Michigan State College in Lansing, Mich., on April 25th and 26th, papers to be read as follows:

"Flame Hardening and Strengthening," by Mr. Flood; "Metallurgy of Welds," F. R. Hensel, R. R., Mallory & Co.; "Welding of Aluminum," by Mr. Hoglund of the Aluminum Co.; "Welding of Stainless Steel," by Mr. Winlock of Edward G. Budd Mfg. Co.; "Stored Energy Welding," by Mr. Humphrey of Taylor-Winfield Corp.; "Pulsation Welding," by Mr. Cogan of National Welding; "Maintenance of Resistance Welding Machines and Electrodes," by Mr. Sieger of the S-M-S Corp.; "Atomic Hydrogen Welding of Copper," by a L. G. Pickhaver, G. E. Co.; "Arc Welding," by H. C. Hettelsater, Harnischfeger; "Electric Control," by Mr. Bedder of Westinghouse Electric.

GEORGIA

The following are the newly elected officers of the Georgia Section: Chairman—Raleigh Drennon, 357 W. Peachtree St. N. E., Atlanta; Vice-Chairman—W. R. Wilburn, 409 N. McDonough Ave., Decatur; Treasurer—Geo. T. Bird, 376 Marietta St., N. W., Atlanta; Secretary—Edward Guillott, 282 Spring St., N. W., Atlanta.

INDIANA

The Indiana Section reports an excellent attendance this season at all meetings, with the average of approximately 125 present.

The Section announces the following programs for April and May.

April 25th—Dinner Meeting, Antlers Hotel. "General Maintenance Welding," by H. O. Jones, Applied Eng. Dept., Air Reduction Sales Co.

May 23rd—Dinner Meeting, Antlers Hotel. Business meeting and election of officers for 1941–42. Open Forum Discussion of Welding Problems.

LOS ANGELES

A local news item, which should be of interest to the SOCIETY in general, concerns present statistics regarding the aircraft industry in Los Angeles County.

At the present time the following figures are accurately listed by a local survey:

Aircraft back log	$1,400,153,354
Employees	62,581
Monthly payroll	10,742,721
New orders for January	4,904,286

The above figures only include the five major aircraft factories and one aircraft motor company in Los Angeles County; these include Northrop, North American Aviation, Vultee Aircraft, Douglas Aircraft and Lockheed Aircraft.

A joint meeting of the A. W. S. Los Angeles Section and the Structural Engineers Association was held on February 13th at the Hotel Clark. "Welding of Structural Steel" was discussed by the following: Mr. Paul Jeffers, Structural Engineer, Mr. Julian P. Stafford, State Division of Architecture; Mr. C. R. Owens, Welding Specialist, General Electric Co.

Mr. Jeffers' talk covered the technical aspect of welding structural steel buildings. He stated that in his opinion technical use of welding had not kept pace with the art of welding. He pointed out that the operators and welding industry as a whole knew a great deal more about welding of structural steel structures than was actually put into use by architects, contractors, etc. Several diagrams and illustrations were drawn to demonstrate various joints showing correct sequence on butt and fillet welds. One of the important points brought out was to never weld steel beams under stress.

Mr. Julian P. Stafford, from the Inspection Department of the State of California, gave some very pertinent information regarding the problems of inspectors and methods of cooperation between the welding engineer and the inspector.

Mr. C. R. Owens tied in the various AMERICAN WELDING SOCIETY electrode specification numbers with various makes of commercial electrodes, stating the advantages and disadvantages of each rod. He also pointed out the necessity of using the right type of rod for the work to be done and advised the structural engineers to acquaint themselves with the various types of rods so that specifications can be included in instructions which will be helpful to the engineers and welders.

NEW YORK

The New York Section held a Joint Technical Meeting with the Metropolitan Section, American Society of Civil Engineers on Wednesday, March 19th at 8:00 P.M. in Room 501, Engineering Societies Building, 33 West 39th Street, New York, N. Y. Joint Chairmen were Mr. J. T. Phillips, Chairman, New York Section, AMERICAN WELDING SOCIETY, and Mr. E. R. Needles, President, Metropolitan Section, American Society of Civil Engineers.

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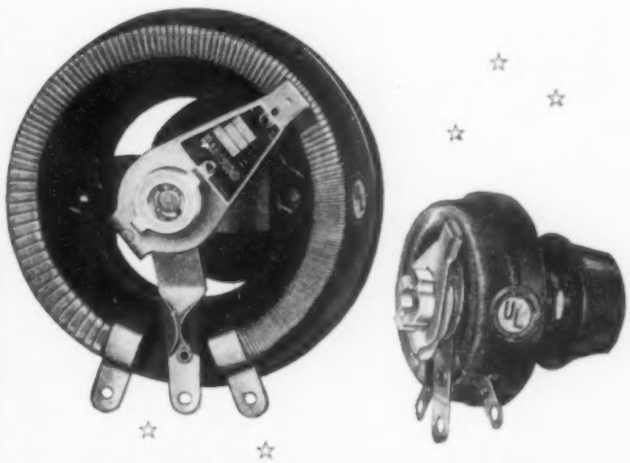

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Colonel Glen F. Jenks, Ordnance Department, U. S. Army, Washington, D. C., and President, AMERICAN WELDING SOCIETY, presented an outstanding lecture on "Use of Welding in National Defense," illustrated by numerous excellent lantern slides.

Mr. LaMotte Grover, Structural Welding Engineer, Air Reduction Sales Company, New York, N. Y., and Member A. W. S., spoke on "The Construction of the Airlines Terminal." His interesting talk was accompanied by a Kodachrome Motion Picture Film which aroused much favorable comment.

Approximately 450 persons attended. The intense interest of the audience was evidenced by the many questions asked following each lecture. Refreshments were served after adjournment and the majority of the assembly remained to enjoy them.

NORTHERN NEW JERSEY

"Welding Monel, Nickel and Inconel in Solid and Clad Plate Constructions" was the subject of a talk which K. M. Spicer, of the Technical Service Section of International Nickel's Development and Research Division, gave at the regular meeting of the Northern New Jersey Section of the AMERICAN WELDING SOCIETY on Tuesday evening, March 18th, in the Oxford Room of the Essex House, 1050 Broad St., Newark, N. J.

Mr. Spicer's discussion covered welding procedures and techniques for gas and electric welding of these materials, properties obtained in the welds and in the welded joints, and typical applications in various industries. The speaker presented slides showing principles of design and the usefulness of welding in fabricating the nickel alloys.

Mr. H. A. Folgner, who has been long in charge of the Industrial Engineering Division of Handy and Harman and has had the opportunity to become very familiar with the subject, spoke on "Silver Brazing Alloys" and explained how these materials can be used to best advantage.

NORTHWEST

A non-technical course on welding is being given by the Northwest Section at a non-member fee of $3.00 and no charge to Section members. The last three conferences are as follows:

April 3rd—"Welding Applied to Pressure Vessels," by E. R. Fish, Chief Engineer, Hartford Steam Boiler Insp. & Ins. Co.

April 8th—"Specifications for Structural Steel Welding as Used by U. S. Engineers," by Floyd O. Borne, Associate Engineer, U. S. Engineers, St. Paul.

April 17th—"Welding of Machinery," by John Mikulak, Mechanical Engineer, Electric Machinery Mfg. Co., at Electric Machinery Mfg. Co., 1331 Tyler Street, N. E., Minneapolis. Commencing at 8:00 P.M.

OKLAHOMA CITY

The Oklahoma City Section held its regular March meeting in the Biltmore Hotel the night of Thursday, March 6th. Despite the inclement weather a crowd of about 65 members and guests was present. The speaker was J. G. Magrath of the Air Reduction Sales Co. of New York City. His subject was "Oxy-Acetylene Treatment of Steel." In addition to being an outstanding lecture, this meeting was distinguished by the amount of discussion which took place both during and after the lecture among the members and the guests on the subject matter of the lecture. Particular emphasis was made on the surface hardening of steels as this procedure is important in many of the industrial applications in oil field territories.

The chairman announced the appointment of a nominating committee for new officers. He also affirmed that the speaker for the next meeting will be Mr. Orville T. Barnett, a former chairman of the Oklahoma City Section. The next meeting will be a dinner meeting on April 10th at the Biltmore Hotel in Oklahoma City. The May meeting will be held on the 8th. "Hard Surfacing" will be presented by E. F. Smith, Haynes Stellite Company.

PEORIA

Mr. L. M. Keating, Manager of Special Products Division, A. O. Smith Corporation, was the speaker at the March 12th meeting of the Peoria Section. Mr. Keating's subject was on "Welding and Mass Production of Special Products." A motion picture, "Safety Glass," was also shown.

PHILADELPHIA

The regular monthly meeting of the Philadelphia Section was held on March 17th. The subject of the meeting was "Building Construction by Welding." A Section Round Table Discussion was led by Mr. H. W. Lawson of Bethlehem Steel Co., assisted by Mr. Wm. Carson, Consulting Engineer, Dr. Bruce Johnston, Asst. Director, Fritz Laboratory, Lehigh University, and Prof. Cyril Jensen, Lehigh University.

PITTSBURGH

Nearly one hundred members and guests attended the February 19th meeting of the Pittsburgh Section in the Mellon Institute Wednesday night to hear Mr. H. P. Schane, Welding Supervisor of the Allis-Chalmers Manufacturing Co., Pittsburgh, Pa., give one of the most interesting and instructive talks ever presented in Pittsburgh on "Resistance Welding." With the aid of many splendid slides Mr. Schane discussed the several types of "Resistance Welding:" spot, projection and seam welding as used in the fabrication of transformer tanks, stating the various applications of each and describing thoroughly the machine settings, die facings, speeds and amperages required. In addition to the slides, Mr. Schane also brought two completely welded tanks, many accessories and test specimens for inspection by those present.

Following the discussion many questions on "Resistance Welding" were asked by those present and were satisfactorily answered by the speaker. Before adjournment those present were pleasantly entertained by the showing of many beautifully colored slides of various scenes taken by Mr. Robinson, also of the Allis-Chalmers Manufacturing Co., on a recent southern trip.

Arrangements have been completed for the Fourth Annual Tri-State Regional Welding Conference to be held jointly with the Engineers Society of Western Pennsylvania in the Cardinal Room of the William Penn Hotel, Pittsburgh, on April 18th. Both afternoon and evening sessions will be held.

Colonel G. F. Jenks, Ordnance Department, Washington, will be the speaker of the evening, and Mr. E. T. Scott, Divisional Vice-President, of Cleveland, Ohio, has been asked to speak a few words on the State of Welding.

For the afternoon session, Mr. J. F. Lincoln, President of the Lincoln Electric Co., Cleveland, will present a talk on "Welding Profits *vs.* Prejudice." This talk will be illustrated with slides, following which the meeting will be thrown open for questions.

The second speaker of the afternoon session will be Mr. David Arnott, Chief Surveyor, American Bureau of Shipping, who will discuss "Welding in Ship Construction."

A six o'clock dinner will be held for those who plan to be present for both sessions, and to get together and renew acquaintances.

ROCHESTER

Mr. Leon C. Bibber, Welding Engineer, Carnegie-Illinois Steel Corp., was the guest speaker at the March 6th meeting of the Rochester Section. Mr. Bibber spoke on "Welded Joints." In general, Mr. Bibber's talk covered different types of joints, explaining the reasons for their use in certain applications and the reasons for not using them. The talk was illustrated by numerous lantern slides and blackboard sketches.

ST. LOUIS

Mr. Tom Jones, Welding Superintendent of South Works of Carnegie-Illinois Steel Corp., addressed the March 14th meeting of the St. Louis Section on "Shop Practice and Resulting Cost." Mr. Jones's main topic was structural welding as far as the shop is concerned.

The April meeting will be held on the 11th. Mr. J. W. Sheffer, Electrical Engineer, American Car and Foundry Co., will speak on "Automatic Spot Welding of Cars."

SOUTH TEXAS

Mr. G. N. Sieger, President and General Manager of S-M-S Corporation, Detroit,

was the guest speaker at the March 12th meeting held at the Texas State Hotel. Mr. Sieger's subject was on "Resistance Welding Electrodes—Their Function and Design." Mr. Sieger illustrated various applications of resistance welding by diagrams and specimens, and discussed the many ways that this method of joining metals is used in the manufacture of present-day automobiles.

The South Texas Section is having an Educational Course on Welding Metallurgy, the text of which was published by the AMERICAN WELDING SOCIETY. The course began on March 24th and will end on May 12th.

TULSA

At the March meeting of the Tulsa Section held at the Mayo Hotel, Mr. J. G. Magrath of the Air Reduction Sales Co. spoke on "Oxy-Acetylene Treatments of Steel." Mr. Magrath's subject covered flame cleaning and dehydrating, descaling, deseaming and scarfing, straightening and bending, hardening and softening, preheating and stress relieving.

WASHINGTON, D. C.

The fifth regular meeting of the Washington Section was held at 8:00 P.M. on Tuesday, February 25th, at the auditorium of the Potomac Electric Power Company. A large audience was present to hear Mr. R. T. Gillette of the General Electric Company in Schenectady give a very interesting and informative talk on "Flash and Other Resistance Welding Processes." The speaker emphasized the importance of design for "Resistance Welding," wherein it is especially necessary to carefully plan a product before ordering its manufacture. A recommended practice is to use scale models and concentrate on reducing the number of parts and number of welds.

The development of equipment for the subject processes was illustrated by slides showing the earliest crude and inefficient manually operated machines followed by successive stages in development to the present modern equipment. A number of slides illustrated equipment for welding motor frames, furnace casings, refrigerator boxes and other quantity production items. An especially interesting development described by the speaker was the operation of welding aluminum and copper without the formation of a brittle zone in the weld. Bend specimens of these welds were shown to possess good ductility. In conclusion, Mr. Gillette showed a high-speed motion picture of a "Flash Welding" operation. The film, operating at normal speed, lasted about ten minutes, while the welding operation took place in a few seconds, thereby providing a detailed visual record of the mechanism of "Flash Welding." Following this, the speaker was occupied for a considerable time with questions and discussion.

WESTERN NEW YORK

Mr. Van Rensselaer P. Saxe, Consulting Civil Engineer, gave a very interesting talk on "Welded Steel Frames Structures" and showed a large number of slides illustrating this work, at the February 21st meeting of the Western New York Section. There was an enthusiastic attendance of about 75 with several members from Erie, Pa., and Rochester, N. Y.

Mr. B. L. Wise, Chief Electrical Engineer, Federal Machine and Welder Co., was the speaker at the March 21st meeting. Mr. Wise spoke on a timely subject—"The Possibility of Resistance Welding in the National Defense Program."

YORK-CENTRAL PA.

On Wednesday, February 19th, the York-Central Pennsylvania Section held its regular monthly meeting. The speaker was Mr. Frederick H. Dill of the American Bridge Company, whose subject was "Recent Developments in Structural Welding." The lecture was illustrated by a fine set of slides that everyone enjoyed. Mr. Dill showed many of the interesting jobs fabricated at Ambridge. A very lively open forum period lasted for about an hour after the regular address.

YOUNGSTOWN

The March meeting of the Youngstown Section was held Tuesday, March 4th, at the Ohio Edison Building in Youngstown, Ohio. The program for the evening was divided into two parts. The first speaker was Mr. R. D. Thomas, President of Arcos Corporation of Philadelphia, who gave a very interesting talk on the arc welding of stainless steel. His talk was generously illustrated by the use of slides.

The second part of the evening was given over to Mr. W. Roy Widdoes, General Manager of Bi-Products Steel Corporation, Coatesville, Pa. His talk was also illustrated with moving pictures in color. The general theme of the picture was a description and showing of the world's largest rolling mill. One particular feature showed the process of transferring a $1^{5}/_{8}$-inch-thick steel plate, weighing $18^{1}/_{2}$ tons, into a 20-foot diameter dome, to be used in the oil-refining business. He also discussed the process of flame cutting and preparing plates for welding. One particularly interesting feature of this part of the discussion was the picturing of how a 15-inch-thick steel plate is flame cut.

The meeting was very well attended, showing that there is a definite interest in this line of work in this section of the country.

The April meeting will consist of a plant inspection of the Federal Machine and Welder Company, Warren, Ohio. At this meeting, Mr. J. W. Meadowcroft, Assistant Works Manager of the E. G. Budd Company at Philadelphia, will be the principal speaker of the evening. The officers are looking forward to a very interesting meeting with a large attendance.

EXPEDITER POSITIONS IN MARITIME COMMISSION

Expediters in marine propelling and outfitting equipment for the U. S. Maritime Commission are being sought for work in the national defense program. The salary is $3200 a year, less the usual retirement deduction. The maximum age limit is sixty-five years. Positions are open now and qualified persons are urged to apply.

Applications will be rated as received at the Commission's Washington office. Further information and application forms may be obtained at any first- or second-class post office, or from the U. S. Civil Service Commission, Washington, D. C.

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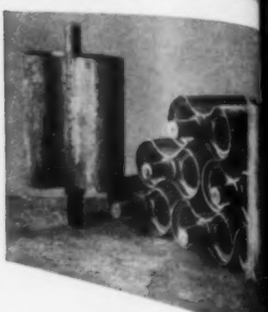
Murex saves time and money in machine parts, as in photograph from United Welding Co., Middletown



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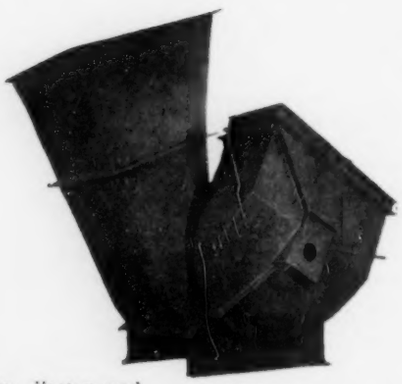

Genex, Vertex and Type FHP Electrodes speed fabrication of this Sirocco Induced Draft Fan for the American Blower Corporation, Detroit.

Cromansil Steel Fire Testing Drive Drum welded by Struthers-Wells, Warren, Pa., with Murex Electrode.

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Recent reports from plants using Murex for production welding show that ...

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. . . quarter inch fillets are made in 30% less time since Murex was adopted by a leading Pennsylvania fabricator.

. . . welding time on pipe flanges was cut from seven hours to 3 hours with Murex.

. . . in a tractor company clutch frame production was stepped up from 8 to 16 per hour.

Murex electrodes have proven again and again their ability to lower production costs, not only because they operate at higher currents, with consequent high speed deposition, but also because they reduce cleaning time—due to a minimum of spatter and an easily removable slag. Furthermore, they handle easily—especially in tight places and vertical and overhead positions.

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